International Journal of Advanced Research in Engineering Technology & Science

ISSN: 2349-2819

Email: editor@ijarets.org Volume-7, Issue-3 March- 2020 www.ijarets.org

BATTERIES: TYPES, WORKING MECHANISMS, IMPORTANCE IN ENERGY STORAGE TECHNOLOGY.

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ABSTRACT

Battery technologies are extremely important in the field of energy storage for a broad variety of applications, such as portable electronic devices, electric cars, and renewable energy systems. There are several different kinds of batteries that are used for energy storage, such as lithium-ion batteries, lead-acid batteries, flow batteries, and sodium-ion batteries. This article takes a comprehensive look at all of these batteries and compares them. In-depth talks on the characteristics, advantages, and limitations of these battery technologies, as well as current breakthroughs and key performance metrics, offer significant insights into the selection and implementation of these battery technologies for a variety of energy storage requirements. Additionally, the article has a comparative analysis that is accompanied by concrete data and tables. This analysis highlights the energy density, cycle life, self-discharge rates, temperature sensitivity, and cost of the various options. This article's objective is to give stakeholders with up-to-date knowledge that will enable them to make educated decisions on the use of battery technologies in energy storage systems. This will be accomplished by searching through the most recent research and literature in the field of battery technologies.

Keywords:- *Batteries types, working mechanisms****,*** *energy storage technology.*

INTRODUCTION

The development of battery technology holds a prominent position at the forefront of scientific and technological innovation in this day and age, when the search for environmentally friendly energy solutions is of the utmost importance. The purpose of this article is to provide a comprehensive analysis and comparison of four common types of batteries that are utilized for the purpose of energy storage. These batteries include lithium-ion batteries (Li-ion), lead-acid batteries, flow batteries, and sodium-ion batteries. The objective is to provide scientists, engineers, and industry stakeholders with a comprehensive understanding of these cutting-edge technologies. This will enable them to make decisions based on accurate information and contribute to the development of energy storage systems.

One of the most important aspects of our efforts to harness renewable energy, reduce emissions of greenhouse gases, and maintain a resilient power infrastructure is the utilization of energy storage resources. In light of the growing worldwide issue of transitioning to sustainable energy sources, it is of the utmost importance to investigate and analyze the complexities of battery technologies that are the foundation of this shift.

The standard for energy storage systems has been established by lithium-ion batteries, which are well-known for their high energy density and are widely used in portable electronic devices and electric cars. Nevertheless, in order to provide a more complete picture, we look into the technologies that have received less attention but are equally promising and have established their own niches within the scope of the subject.

Lead-acid batteries, which have a long history of use in automotive applications and grid storage, continue to provide solutions that are both reliable and economical. The most recent developments have revitalized their potential, which has resulted in them being thrust back into the spotlight.

The way that we think about energy storage systems has undergone a paradigm shift as a result of flow batteries, which are praised for their adaptability and scalability in large-scale energy storage and grid applications. As a result of their amazing potential to store and discharge energy in an efficient manner, as well as their extended cycle life, they are an intriguing subject of research.

In conclusion, sodium-ion batteries, which are relatively new to the market, hold the potential to be an environmentally beneficial and sustainable method of energy storage due to the fact that they make use of materials that are based on sodium. A peek into the prospective future of energy storage solutions is provided by these technologies, which are still in the process of undergoing extensive research and development.

Objectives

1. To studyBatteries types.
2. To studyGrid applications of a battery storage.
3. To study Battery technology comparison

Battery technologies overview

At the same time that smart grids and microgrids are being developed, there is an increasing demand for energy storage facilities inside power systems. Throughout the course of human history, numerous storage methods have been devised for the purpose of storing electrical energy. The most significant distinction between the various types of storage is the type of energy that is used to store electrical energy from one type to another. Storage can be classified into the following categories: mechanical, thermal, thermochemical, chemical, electrochemical, electrical, and magnetic. Flywheels, pumped hydro, and compressed air are the primary technologies that are utilized for mechanical storage. The technologies of capacitors and supercapacitors are used for the storage of electrical energy. Fuel cells that run on hydrogen are the primary technique for storing chemicals.

This article discusses batteries, which are a type of storage device that utilizes electrochemical reactions. The various sorts of battery technologies will be discussed in detail. There are a variety of battery technologies. It is also possible to use flow battery technologies, and one of these will be discussed in more detail. The following techniques for the production of batteries are discussed in this article:

- lead-acid,
- lithium-ion,
- nickel-cadmium,

- nickel-metal hydride,
- sodium-sulfur,
- vanadium-redox flow.

An overview of the various battery technologies that are listed is presented in accordance with their various technical qualities. The following is a definition of the observed technical qualities. The voltage that is measured on the battery cell between the positive and negative terminals is referred to as the cell voltage, or V. For the purpose of stacking cells into batteries with a voltage that has been previously defined, it is of utmost importance.

The term "specific energy" (Wh/kg) refers to the amount of energy that may be collected by battery technology for each unit of mass. In order to compare the amount of energy that is produced by several technologies that have the same mass, it is essential.

The term "specific power" (W/kg) refers to the amount of power that may be extracted from a battery technology per unit of mass. When comparing the output power of several technologies with the same mass, it is essential to have this information.

The amount of energy that can be extracted from a given volume of battery technology is referred to as its energy density, which is measured in kilowatt-hours per cubic meter. It is essential for comparing the amount of energy that is produced by various technologies that have the same volume capacity.

Power density, measured in kilowatt-hours per cubic meter, is a measure of the amount of power that can be extracted from a material. When comparing the output power of several technologies with the same volume, it is essential to have adequate information.

As a percentage, efficiency represents the proportion of energy that can be discharged from a battery to the amount of energy that is consumed to charge the battery. During the process of converting energy from electrical to electrochemical, as well as during the process of converting electrochemical energy back into electrical energy, there are losses.

The temperature range at which the battery technology is able to function is referred to as the working temperature, which is [°C]. There is a possibility that the performance of the battery will suffer significantly if the temperature falls outside of this range.

There are a certain number of charge and discharge operations that the battery must go through in order to maintain its minimal functioning performance. This is referred to as the lifetime cycles. Because there are a significant number of cycles, it is essential for applications that involve a great deal of charging and discharging processes or procedures.

The term "lifetime" refers to the number of years that the battery maintains its minimal level of performance while in use. If a battery has a short lifespan, it will need to be replaced frequently, which can be an expensive endeavor.

- **Lead-acid**

  As a result of the fact that it is simple and inexpensive to install and maintain, lead-acid (Pb-acid) technology has been in use for a considerable amount of time. This is the primary reason for the widespread use of this technology, and it is also one of the most popular technologies used for stationary applications all over the world.

- **Lithium-ion**

  When it comes to battery technologies, lithium-ion (Li-ion) technology is among the most advanced and commonly used technologies available today. Each and every electronic device, including mobile phones, tablets, laptops, and smartphones, is powered by a Li-ion battery. Among the many advantages of lithium-ion technology are its high power, energy capacity, long battery lifetime, and comparatively low weight. As a result of these advantages, lithium-ion technology is currently being utilized to power hybrid and electric vehicles.

- **Nickel-cadmium**

  Nickel-cadmium (Ni-Cd) technology has been utilized for a considerable amount of time in applications that call for a lengthy battery life and in challenging environmental conditions. This is due to the fact that this battery technology is both inexpensive and reliable. Electrolyte for nickel-cadmium batteries is potassium hydroxide, while the cathode is formed from nickel oxide hydroxide and the anode is made from metallic cadmium. Nickel-cadmium technology is based on these two components respectively.

- **Nickel-metal hydride**

  The nickel-metal hydride (Ni-MH) technology has been utilized in a variety of applications, including the storage of energy for intelligent energy systems, the development of robust battery systems that are able to function at high temperatures, hybrid electric vehicles, and public transportation.

- **Sodium-sulfur**

  The sodium-sulfur (NaS) battery technology is one of the most ideal for use in energy storage systems due to the high energy density that it possesses.

- **Vanadium-redox flow battery**

  Because of its very good qualities, the vanadium-redox flow battery, also known as VRFB, is a relatively new technology that holds a great deal of potential. For the purpose of long-term energy storage, this technology is suitable since it has a long lifetime, a very fast response time, and a lengthy storage time.

Grid applications of a battery storage

The amount of distributed generation increases, which causes passive distribution grids to become active inside the system. This indicates that energy travels in two different directions: first, from the generating grid to the distribution grid, then from the transmission grid to the distribution grid, and finally, from the distribution grid to the transmission grid. When compared to the operation of a passive grid, the operation of an active distribution grid is more sophisticated. This is especially true in situations when dispersed generation is intermittent, such as when wind and photovoltaic power are being used. There is a requirement for extra energy storage that is capable of supporting the functionality and stability of the grid. In conventional power systems, the load profile is separated into two categories: a base load, which is covered by power plants that operate at baseload, and a variable load, which is covered by power plants that operate under load following conditions. In order to reduce the amount of power plants that are required for regulation, variable load can be partially handled by energy storage resources. Due to the rapid response that batteries have to changes in voltage and frequency, they are more suitable for use in applications that require voltage and frequency regulation than power plants that regulate voltage and frequency. The following grid applications are examples of where batteries are being utilized:

- peak shaving,
- load leveling,
- power reserve,
- integration of renewable energy sources,
- voltage and frequency regulation,
- uninterruptible power supply.

The highest demand for electrical energy occurs in the evening during the winter months because of the high amount of energy that is required for heating, and in the middle of the day during the summer months because of the high amount of energy that is required for cooling.

There is not much of a difference between peak shaving and load leveling. Applications that use booths operate according to comparable concepts.While there is a low demand for power, energy is being stored in batteries, and when there is a high demand for power, energy is being drawn from the batteries.

Grid operators have the ability to anticipate the load demand for the day ahead, and it is possible that the real load demand will be lower than the expected load demand. On the other hand, it is also possible that the actual load demand may be higher than the predicted load demand.

The use of renewable energy sources is becoming increasingly widespread around the globe, and their proportion of the overall generation of electrical energy is continuously increasing. When renewable energy sources, particularly wind and solar, are integrated into the grid, grid operators face issues that are both economically and technically challenging.

It is necessary to carry out voltage and frequency maintenance in the power system in order to ensure that the power system remains stable.The reactive power is responsible for regulating the voltage, while the active power will be responsible for regulating the frequency. The voltage and frequency fluctuations that occur in power systems that incorporate renewable energy sources are more significant and occur more frequently; thus, there is a requirement for more sophisticated voltage and frequency regulation systems.

In the event of a power loss or a state of emergency, the purpose of uninterruptible power supplies, also known as UPS, is to ensure that electrical and electronic devices continue to get a steady source of power. The usage of uninterruptible power supplies (UPS) is often reserved for critical applications, which are those in which even a brief interruption in the main power supply can have major or even potentially hazardous repercussions.

Battery technology comparison

In order to provide a more accurate comparison of technologies, the following six diagrams, which are uniformed, are used to provide a comparison of attributes. In the first four diagrams, which are two-dimensional, one of the characteristics of the technology is displayed along the x-axis, while another is displayed along the y-axis. Each of the two most recent graphics is a one-dimensional representation; the x-axis displays the various battery technologies, while the y-axis displays the characteristics of the technology.

Presented in Figure 1 is a diagram that illustrates the specific power and specific energy that are associated with various battery storage systems. Vanadium-redox flow batteries, lead-acid batteries, nickel-cadmium batteries, and nickel-metal hydride batteries are the ones with the lowest specific power and specific energy. However, the specific energy of sodium-sulfur technology ranges from 150 to 240 Wh/kg, despite the fact that it has a low specific power. While the specific energy of the lithium-ion battery technology ranges from 80 to 250 Wh/kg, the specific power ranges from 200 to 2000 W/kg, which is higher than the specific energy and power ranges of other technologies.

The diagram that is given in Figure 2 illustrates the power density and energy density of several battery storage methods. The power density of a vanadium-redox flow battery ranges from 2.5 to 3 kW/m3, and its energy density ranges from 10 to 33 kWh/m3. Both of these capacities are quite low. Because there is a significant amount of space required for the deployment of two electrolyte tanks. Compared to other technologies, the energy density of li-ion technology ranges from 95 to 500 kWh/m3, and its power density ranges from 50 to 800 kW/m3, making it more efficient than other technologies.

Presented in Figure 3 is a diagram that illustrates the power cost and energy cost associated with various battery storage methods. Lithium-ion batteries are the most expensive battery technology, with power costs ranging from 1,000 to 3,400 euros per kilowatt-hour and energy costs ranging from 500 to 2,100 euros per kilowatt-hour. The lead-acid battery technology has the lowest price, with power costs ranging from 250 to 500 euros per kilowatt-hour and energy costs ranging from 40 to 170 euros per kilowatt-hour.

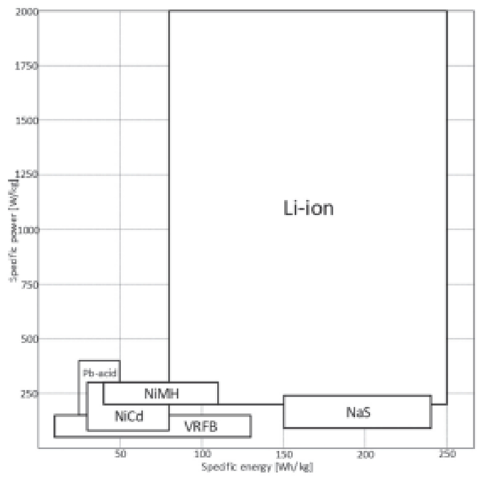

Fig. 1. Specific power to specific energy

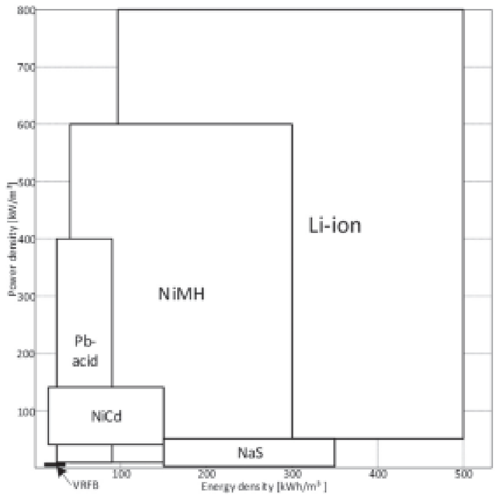

Fig. 2. Power density to energy density

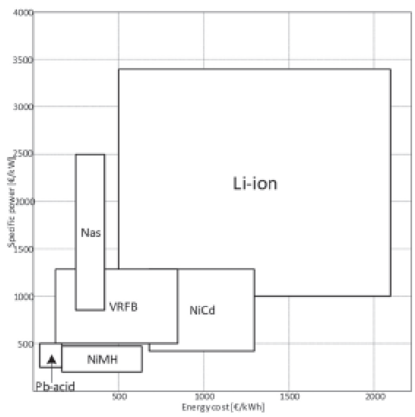

Fig. 3. Cost of battery technologies

Conclusion

Battery technologies continue to be at the forefront of producing energy storage solutions that are both efficient and long-lasting across a wide variety of industries. When it comes to picking the most appropriate technology for certain energy storage needs, having a comprehensive awareness of the characteristics, benefits, and limitations of the many types of batteries, as well as the current breakthroughs in these sorts of batteries, is essential. For particular applications, lead-acid batteries continue to perform exceptionally well, despite the fact that lithium-ion batteries continue to hold a strong position in the market. Flow batteries and sodium-ion batteries have a great deal of potential for the storage of energy on a massive scale. These batteries are now the subject of continuous research and development efforts that are aimed at improving their performance and tackling important difficulties. In order for stakeholders to be able to contribute to the shift towards sustainable energy and the realization of effective energy storage solutions, it is necessary for them to remain current on the most recent revolutionary developments in battery technology.

The purpose of this article is to provide an overview of six different battery technologies that are most frequently utilized for grid applications. There is a presentation of the primary properties of lead-acid, lithium-ion, nickelcadmium, nickel-metal hydride, sodium-sulfur, and vanadium-redox flow batteries, as well as a comparison of these qualities. However, it is not possible to draw the conclusion that one technology is superior to others. Some battery technologies are well-suited for a variety of applications, whereas others have a particular use in which they have demonstrated exceptional performance. Every single battery technology is suitable for use in environments with moderate climate conditions; however, only a select few technologies are able to endure the challenges of being used in environments with extreme climatic conditions.

REFERENCES

1. Y. Hua, X. Shentu, Q. Xie, Y. Ding, “Voltage/Frequency Deviations Control via Distributed Battery Energy Storage System Considering State of Charge”, Applied Sciences, Vol. 9, No. 1148, 2019.

2. Y. R. Challapuram, G. M. Quintero, S. B. Bayne, A. S. Subburaj, M. A. Harral, “Electrical Equivalent Model of Vanadium Redox Flow Battery”, Proceedings of the IEEE Green Technologies Conference, Lafayette, LA, USA, 3-6 April 2019.

3. S.S. Zhang, et.al, Lead-Acid Batteries and their Latest Developments. In Lead-Acid Batteries: New Materials, Applications, and Advances (pp. 1-15). Wiley (2022)

4. P. Leung, et.al, Materials Today Energy 20, 100752 (2021)

5. W. Chen, et.al, Advanced Energy Materials 12(7), 2102183 (2022)

6. H. Jiang, et.al, Small 18(3), 2104676 (2022)

7. S.S. Zhang, G. Li, Advanced rechargeable batteries: Materials, technologies, and perspectives. Springer (2021)

8. Battery University. (n.d.). Nickel-Cadmium (NiCd). Retrieved from https://batteryuniversity.com/learn/article/nickel_cadmium

9. Battery University. (n.d.). Nickel-Metal Hydride (NiMH). Retrieved from https://batteryuniversity.com/learn/article/nickel_metal_hydride

10. S. K. Fayegh, M.A.Rosen, "A review of energy storage types, applications and recent developments", Journal of Energy Storage, Vol. 27, 2020.

11. X. Fan, B. Liu, J. Liu, j. Ding, X. Han, Y. Deng, X. Lv, Y. Xie, B. Chen, W. Hu, C. Zhong, "Battery Technologies for Grid Level Large Scale Electrical Energy", Transaction of Tianjin University, Vol. 26, No. 2, 2020, pp. 92-103.

12. Y. Cho, H. A. Gabbar, "Review of energy storage technologies in harsh environment", Safety in Extreme Environments, Vol. 1, 2019, pp. 11-25

13. T. Chen, Y. jin, H. Lv, A. Yang, M. Liu, B. Chen, Y. Xie, Q. Chen, "Applications of Lithium Ion Batteries in Grid Scale Energy Storage Systems", Transactions of Tianjin University, Vol. 26, No. 3, 2020, pp. 208-217.

14. Z. Xio, L. Du, X. Lv, Q. Wang, J. Huang, T. Fu, S. Li, "Evaluation and Analysis of Battery Technologies Applied to Grid Level Energy Storage Systems Based on Rough Set Theory", Transactions of Tianjin University, Vol. 26, 2020, pp. 228-235.

15. M. Sufyan, N. A. Rahim, M. M. Aman, C. K. Tan, S. R. Raihan, S. R. S. Raihan, "Sizing and applications of battery energy storage technologies in smart grid system: A review", Journal of Renewable and Sustainable Energy, Vol. 11, No. 1, 2019, p. 014105.

16. M. Vins, M. Sirovy, "Sodium-Sulfur Batteries for Energy Storage Applications", Proceedings of the 20th International Scientific Conference on Electric Power Engineering, KoutynadDesnou, Czech Republic, Czech Republic, 15-17 May 2019.

17. O. Adeleke, A. Ukil, X. Zhang, "Vanadium Redox & Lithium Ion Based Multi-Battery Hybrid Energy Storage System for Microgrid", Proceedings of the IEEE PES Asia-Pacific Power and Energy Engineering Conference, Macao, 1-4 December 2019.

18. M. Simeon, A. U. Adoghe, S. T. Wara, J. O. Olowni, "Renewable Energy Integration Enhancement Using Energy Storage Technologies", Proceedings of the IEEE PES/IAS PowerAfrica, Cape Town, South Africa, 28-29 June 2018, pp. 864-868.