REVIEW ON SUPERCAPACITOR AS ENERGY STORAGE SYSTEM

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Abstract - Supercapacitors are one of the promising components for future generation energy storage devices. The creation of advanced electrode materials and processes for their fabrication is one way to maximize the energy storability of supercapacitors. The objective of the proposed project is to develop a supercapacitor that serves as a battery-free power source powered by a photovoltaic cell. The supercapacitor will be fabricated using $MnCo_2O_4$ as an anode, activated carbon as a cathode and KCl as an electrolyte.

The supercapacitor is a bridge between the electrolytic capacitor and rechargeable batteries. Glowing the LED using supercapacitor results in delivering the energy very quickly, making them perfect complements to batteries. Supercapacitors have the benefit of having a huge amount of power storage capacity. The supercapacitors comprise two important storage factors like high specific capacitance and maximum charging voltage. Overall, Supercapacitors offer a promising alternative to conventional batteries for applications that require high power density, fast charging-discharging, and long cyclic stability. However, contrary to supercapacitors, conventional batteries suffer from ageing whether they are in use or not. Hence, using a supercapacitor in places of batteries lasts longer as it stops accepting any energy once it is full.

Index Terms – Capacitor, Manganese Cobalt Oxide ($MnCo_2O_4$), Potassium Chloride (KCl), Supercapacitor

I. INTRODUCTION

The world's expanding human population has also increased the demand for energy at the same time. It is crucial to develop environmentally friendly energy generation and storage technologies, such as electrochemical supercapacitors and batteries. Only if the energy acquired from these sources can be adequately stored will the maximum benefit from them be realised. Supercapacitors can replace batteries because of their high capacitance, low discharge rate, extended cycle stability, and tiny size. It can supply a current of up to 1-100mA, guard against power outages for microcomputers, and store the contents of complementary metal-oxide semiconductor (CMOS) for a long time. Two electrodes will be maintained apart by a separator in electrochemical supercapacitors [1].

The performance of supercapacitors is primarily influenced by the properties of the electrode materials and electrolyte contact. Because of its inexpensive cost, manufacturing methods, tuneable surface area, pore shape, surface chemistry, and pore size distribution, porous carbon materials are thought to be more beneficial than other accessible electrode materials. Several techniques, including electrochemical deposition, chemical vapour deposition, and the sol-gel method of chemical bath deposition, are used to synthesise supercapacitor materials. Similarly, many techniques for creating electrodes include inkjet printing, spray coating, and direct writing. Due to its large surface area, controlled pore size distribution, and inexpensive cost in comparison to other carbon materials, activated carbon is utilised as a cathode [2].

Areca nut fibres, which are abundant in high-quality lingo-cellulosic fibres and have potential applications in a variety of industries, are used to make activated carbon. Chemical vapor deposition (CVD) is used to synthesize carbon materials. Due to its broad potential range, strong electrochemical activity, and environmental friendliness, manganese cobalt oxide ($MnCo_2O_4$) is used as an anode. Lithium hexafluorophosphate ($LiPF_6$), potassium hydroxide (KOH) and potassium chloride (KCl) are used as electrolytes while fabricating the cells.

II. LITERATURE SURVEY

N. K. Bhattacharya *et al.*,[3] proposed the application of supercapacitors to power-limited photoelectric machines. It has been shown that supercapacitors may be charged and discharged inside a tiny electrical device. Supercapacitor module charging from a solar module is used to charge Li-ion batteries, combined with a constant voltage converter. The charging component for supercapacitors, which are employed in remote locations, is proposed in this study together with a compatible PV module. For remote consumers who are not connected by a utility framework, using supercapacitors in a safe method offers good potential. In terms of quick charging and meeting the necessary power utilisation, the designed circuit has produced encouraging results.

P. U. Shinde *et al.*,[4] describe supercapacitors as an energy storage system. The electrode, electrolyte, and separator are the three basic components of a supercapacitor, which is an energy storage device. To achieve the highest capacitance from a supercapacitor, a suitable combination of the terminal and electrolyte materials is required. While supercapacitors have higher power densities and lower energy densities than batteries, conventional capacitors are weaker and have less power density. The modelling and simulation of supercapacitor covering of diffused capacitance with low internal resistance outline the arrangement of supercapacitors, their characteristics, disadvantages, and carefulness while utilizing them.

Nayan Tale ***et al.*****,**[5] illustrate the late upgrades in supercapacitors. The structures and characters concerning this capacity framework have been described. Physical custom, determinable demonstration of supercapacitors is more studied. It does include both benefits and troubles of supercapacitors. It is determined that the supercapacitors can increase circuit accomplishment on account of extreme power bulk and strength to act in extreme temperatures. This can increase the worth to the product and ultimately lower the cost by lowering the amount of batteries required which results in environmental friendliness.

M. Al-Ramadhan ***et al.*****,**[6] propose a supercapacitor energy storage system for use in renewable energy applications. To use supercapacitor energy storage system "SCESS" as a potential storage for STATCOMS. They are used to provide power stability systems. Compared to batteries supercapacitors have lower energy storage but higher power exchanging capability. This study, design, and control of a supercapacitor energy storage system (SCESS) for a STATCOM are presented in this paper. To control the SCESS system a peak current controller is used. The proposed SCESS system shows excellent performance in the simulation results of the SCESS system. The research's test results demonstrate that the SCESS system can maintain the dc link voltages necessary for the STATCOM-SCESS to exchange real power with the system.

Prasit Phoosomma ***et al.*****,**[7] specifies about the applications of supercapacitors as an emergency lighting power source. It also sheds light on the design of supercapacitor charging and discharging in LED emergency lighting rated 10-12V. The charging process takes 10 minutes to reach a voltage of 15.4V, but in the event of a power outage, the control circuit directs the supercapacitor to release its charge to the LEDs for 10 minutes, or until the voltage of the energised material falls to 3.94V. Additionally, supercapacitors have been replenished for when the power system is back to normal. On finding the supercapacitor used for emerging lighting, designing of charging, and discharging circuit is created.

Britta Andres ***et al.*****,**[8] explain the supercapacitors with graphene-coated paper electrodes and gives the fundamental information that to create paper-based supercapacitors, two graphene electrodes are wetted with a liquid electrolyte before being stacked with paper. Two types of approaching material, silver, and graphite foil, were recognised as different terminal components. In the centre of the supercapacitor, paper can also be employed as an ion-penetrable separator. Supercapacitors accompanying paper elements can be created by utilizing justified paper-making automation. The scalability of the low-cost outcome, the cheap materials, and the wide range of potential applications are the key benefits of supercapacitors with graphene-paper electrodes.

Robert Brooke ***et al.*****,**[9] describe a scalable method for creating custom paper-based supercapacitors, according to the journal abstract. They produce supercapacitors of various sizes, including a big supercapacitor with a capacitance of 200F, to show the viability of their technology. The possible uses of these supercapacitors are also covered in the article, including energy storage for renewable sources and portable electronics.

Er. Abhinav Dogra ***et al.*****,**[10] projected an ultra-capacitor as a source for smart streetlight. One of the biggest causes of electricity losses is the unnecessary energy waste in street lighting. Promoting a battery less self-sufficient smart street lighting system (BAISL) for widespread use is the aim of this project. By using light sensors, motion sensors, and a smart control system, the system may autonomously adjust the streetlight depending on the brightness of the surroundings. In this system, the streetlights are practically independent and will not require any power supply. This system needs an even more complex controller which can increase its efficiency.

Praanav Lodha ***et al.*****,**[11] describe how lithium-ion batteries are made and how they store charge. Additionally, it covers the materials typically utilised for electrodes and their designs as well as the terminal reactions in lithium-ion batteries. In addition to other pertinent differences, the electrochemical efficiency of several types of lithium-based batteries was studied. After explanations of the charge storage mechanism and the advancement of battery supercapacitor hybrids, a brief section on their evolution over the previous two decades is included. In light of the current electrochemical energy storage technology, battery supercapacitor hybrids are distinguished.

Anshika Goel ***et al.*****,**[12] depict that less energy-density supercapacitors cannot be used in commercial parts. Graphene-based electrodes are employed in supercapacitors to overcome this limitation, which results in excellent stability but lacks high values of specific capacitance. This review paper summarises the most recent research on using supercapacitors made of alloy oxides and conducting polymers as well as graphene to store energy efficiently. Today's supercapacitors are an improved type of capacitor with a cutting-edge design, good power density, the ability to store a lot more energy, a long cycle life, quick charge and discharge, the ability to withstand high temperatures, and environmental friendliness. As a result, supercapacitors are closing the gap between regular batteries and traditional capacitors. If supercapacitors are manufactured correctly, they will be able to replace batteries.

Rohullah Tofan ***et.al.*****,[**13] suggest a hybrid energy storage system for electric vehicles that are made up of a battery and a supercapacitor. Through simulations, they show how the inclusion of a supercapacitor can increase the electric vehicle's overall efficiency and battery life. The essay also explores the benefits and drawbacks of this hybrid system and offers suggestions for further investigation.

Mohammad Hadin. A ***et al.*****,**[14] proposed a battery-less power supply using a supercapacitor as energy storage powered by solar. The supercapacitor act as a power supply to charge a low-power device wirelessly. To charge the supercapacitor, solar energy is used as a backup power supply if there is no electricity in remote areas. This project uses wireless power transfer (WPT) to transmit electricity by overlapping magnetic fields. This study can also be used to power up any photoelectric device such as a flashlight, DC motor, or speaker for users while travelling. By combining supercapacitors with battery or renewable energy it can deliver high energy which will be hybrid in future

S. K. Kandasamy ***et al.*****,**[15] describe a method for creating activated carbon from solanum tuberosum (potato) starch and chemically modifying it to enhance its electrochemical characteristics. By employing the modified activated carbon as electrode material in a supercapacitor, they show the potency of their strategy. The findings of different experiments performed on the supercapacitor, including cyclic voltammetry, galvanostatic charge-discharge, and impedance spectroscopy, are covered in the paper. The testing revealed that the supercapacitor had excellent cycling stability and high specific capacitance. The potential use of solanum tuberosum starch as a reasonably priced and ecologically friendly precursor for the production of activated carbon for use in energy storage applications.

J. Chen ***et al.*****,**[16] provide an overview of the current state of understanding of the mechanisms underlying supercapacitor operation and discuss recent advances in the development of multifunctional supercapacitor systems. The article discusses the various types of supercapacitors, including aqueous and non-aqueous electrolyte-based systems, and describes the materials used for their electrodes. The article also describes the recent progress made in the development of supercapacitors with multiple functions, such as energy storage, sensing, and actuation. The authors discuss the potential of these multifunctional supercapacitors in various applications, such as wearable electronics, robotics, and environmental monitoring.

R. Ramachandran ***et al.*****,**[17] describe various electrochemical energy storage devices, including batteries, fuel cells, and supercapacitors, and discuss their basic principles of operation. The article also describes the various characterization techniques used to study the morphological features of supercapacitors, such as scanning electron microscopy (SEM), transmission electron microscopy (TEM), and X-ray diffraction (XRD). The authors discuss the advantages and limitations of each technique and highlight their importance in understanding the electrochemical properties of supercapacitors. The article concludes by discussing the challenges in the development of supercapacitors, such as improving their energy density, cycle life, and sustainability.

K. Sahay ***et al.*****,[**18] give an overview of supercapacitor-based energy storage systems for power quality improvement. The article discusses the advantages of supercapacitors over batteries, such as their high-power density, fast charging and discharging rates, and longer cycle life. The article also describes the various applications of supercapacitors in power quality improvements, such as voltage and swell mitigation, peak shaving, and renewable energy integration. The authors provide a detailed analysis of the performance of supercapacitors in each of these applications, highlighting their effectiveness in improving power quality and reliability. In addition, the article discusses the challenges in the development of supercapacitor-based energy storage systems, such as improving their energy density and reducing their cost.

J. Chmiola ***et al.*****,**[19] described the two main types of supercapacitors: Electrochemical capacitors (ECs) and pseudo capacitors. ECs store charge by adsorption and desorption of ions at the electrode surface, while pseudo-capacitors store charge through reversible redox reactions at the electrode surface. The authors discuss the advantages and disadvantages of each type of supercapacitor and describe the various materials that can be used as electrodes in both types of devices. The authors also discuss the various techniques that are used to characterize supercapacitors, including electrochemical impedance spectroscopy (EIS), cyclic voltammetry (CV), and galvanostatic charge-discharge cycling. They also describe some of the challenges that must be addressed to improve the performance of supercapacitors, such as reducing internal resistance and increasing energy density.

Ahmed. S ***et al.*****,**[20] provide an overview of the basic principles of supercapacitor operation and then goes on to discuss the various types of supercapacitors and their applications in renewable energy systems. The authors begin by describing the advantages and disadvantages of using supercapacitors for energy storage in renewable energy systems, including their high-power density, long cycle life, and fast charge and discharge times. The authors also discuss the various techniques that are used to model and simulate supercapacitor-based energy storage systems, including mathematical modelling, simulation software, and experimental testing. They also describe some of the emerging trends in supercapacitor technology, such as the development of new electrode materials and the integration of supercapacitors with other energy storage technologies, such as batteries and fuel cells.

X. Zhang ***et al.*****,**[21] provide a comprehensive review of the use of graphene-based materials for supercapacitor electrodes. The paper provides an overview of the basic principles of supercapacitor operation and then goes on to discuss the various types of graphene-based materials that can be used as electrodes in these devices. The authors begin by describing the advantages of using graphene-based materials for supercapacitor electrodes, including their high surface area, excellent electrical conductivity, and good mechanical stability. They also discuss the various types of graphene-based materials, including graphene oxide (GO), reduced graphene oxide (rGO), and three-dimensional (3D) graphene-based materials, and describe the methods that can be used to prepare these materials. Finally, the paper concludes with a discussion of the prospects for graphene-based supercapacitor electrodes, including the potential to develop new hybrid materials.

P. Simon *et al.*,[22] proposed a detailed overview of the principles of supercapacitors, their classification, and their electrochemical behavior. The authors discuss the differences between supercapacitors and other energy storage devices, such as batteries and conventional capacitors. They also provide an in-depth analysis of the various types of supercapacitors, including electrochemical double layer capacitors (EDLCs), pseudo capacitors, and hybrid capacitors. The review also covers the development of new materials for supercapacitor electrodes, including carbon-based materials, metal oxides, and conducting polymers. The authors discuss the advantages and limitations of each material and how they can be optimized for specific applications. In addition, the article provides an overview of the different electrolytes used in supercapacitors, including aqueous and non-aqueous electrolytes, and their impact on performance.

III. SUMMARY AND OBSERVATION

The supercapacitor is a bridge between the electrolytic capacitor and rechargeable batteries. Glowing the LED using supercapacitor results in delivering the energy very quickly, making them perfect complements to batteries. While batteries can provide ~10x more energy over much longer periods of time than a supercapacitor can, supercapacitors can deliver energy ~10x quicker than a battery.

Supercapacitors offer several advantages over conventional batteries, including high power density, fast charging and discharging, and long cycle life. They are perfect for high-power applications like electric and hybrid vehicles since they can deliver bursts of power in a brief period of time. Supercapacitors also have a lower risk of fire than batteries because they don't contain flammable electrolytes. Supercapacitors can be used for energy storage applications that need high energy density; however, they are less energy dense than batteries. Overall, supercapacitors offer a promising alternative to conventional batteries for applications that require high power density, fast charging and discharging, and long cycle life.

This paper has displayed the importance and application of supercapacitors and a survey of late improvements. It also displays supercapacitors as a replacement for batteries because of their high efficiency. The structure and qualities of these power framework has been depicted and the physical usage and quantitative demonstration of the supercapacitors has been studied.

IV. CONCLUSIONS

Batteries are not robust as other rechargeable technologies. They require protection from either being overcharged or discharged too far. In addition to this, the current must be maintained within the safe limits. Often batteries suffer from ageing whether they are in use or not. So, by using a supercapacitor in place of batteries it lasts longer as the Supercapacitor will stop accepting any energy once it is full. They also provide significant cost savings. In-depth research on the supercapacitor modelling foundation, which serves as the foundational process to be followed during prototype development, is done in this review. An overview of the analysis, use, and disadvantages of supercapacitors is also reported.

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