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Energy Storage System Designing & Performance Measures

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ABSTRACT
For the past 20 years, Li-ion batteries have become the most widely used battery due to their high energy density and rechargeable capabilities. However, while the uses of Li-ion batteries are many, they still fall short in large-scale energy storage applications. Therefore, the alternatives needed are investigating different energy storage systems. Titanium disulfide is a transition metal dichalcogenide with a layered structure that Van der Waals forces hold together.
Herein, TiS2 nano sheets are synthesized from bulk TiS2 using electrochemical intercalation. The effectiveness of the electrochemical intercalation is assessed by altering specific parameters such as time of discharge and current being applied. By using thick electrodes made from bulk TiS2, the study revealed that intercalation is most effective at a slow rate as a high current rate causes significant polarization and voltage drop. The design of efficient and cost-effective bi-functional electro catalysts for oxygen reduction and evolution reactions is crucial for metal-air batteries. Porous manganese oxide spheres, combined with different carbon additives, are used as a bi-functional catalyst in Zn-air batteries.

INTRODUCTION

The increasing energy demand has caused the development of sustainable energy storage systems that yield high energy density. Energy storage is essential to address the current global crisis28, 29.
Research has over the years concentrated on cutting back on the use of fossil fuels and CO2 emissions. Due to the unpredictable power production of these new energy sources, the use of wind and solar energy has raised the need for energy storage. While carbon dioxide emissions from energy consumption have reduced by over 23% over the past few years, the United States' usage of renewable energy has surged by nearly 700% between 2012 and 2020. 30. A promising power source, metal-air batteries have a high specific energy, are economical, and are ecologically friendly 31.
In addition, the open system provides an infinite supply of oxygen from the atmosphere, allowing high energy density to be possible32. Metal air batteries can consist of pure metals such as lithium, sodium, aluminum, or zinc as an anode and a catalyst loaded on a gas diffusion layer (GDL) as a cathode allowing infinite air absorption.
Metal-air batteries are safer to use as they consist of an aqueous or solid electrolyte that is nonflammable and less toxic than the conventional organic electrolytes of lithium-ion batteries. However, while lithium-air batteries have the highest theoretical density, their metallic form is unstable in atmospheric conditions. Magnesium suffers from low potential reduction, and the same applies to aluminum batteries.

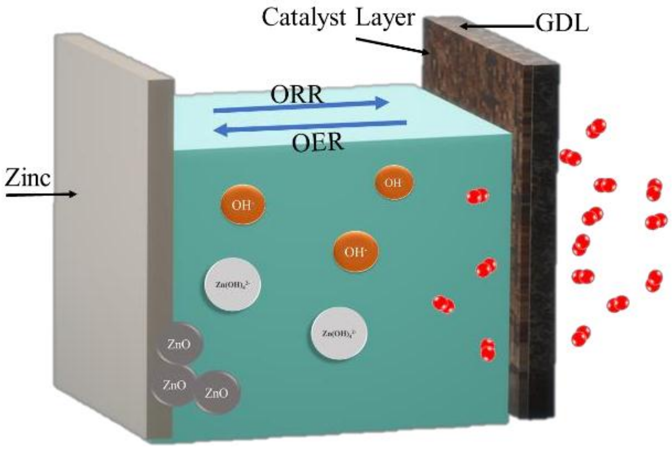

Figure 1: Schematic of a Zinc-air battery with oxygen molecules (red), hydroxide ions (orange), zincate ions (light grey) and zinc oxide (grey)

LITERATURE REVIEW

[1] Massoud Pedram, Naehyuck Chang, Younghyun Kim, and Yanzhi Wang, "Hybrid Electrical Energy Storage Systems" 2010
Produce HEES design factors, such as To maximise the amortised cost for the system, consideration should be given to the original cost (cost per capacity), operating cost (efficiency), maintenance cost (cycle life and disposal cost), and so on.

[2] Francisco Sanchez, Joshua Cayenne, Francisco Gonzalez-Longatt, José Luis Rueda, "Controller to enable the enhanced frequency response services from a multi-electrical energy storage system" 2018
The Great Britain (G.B.) power system's reduced inertial responsiveness, which translates into more significant frequency changes in transient and pseudo-steady-state operation, results from the increased use of renewable energy sources. The transmission system operator in Great Britain, National Grid, has created an enhanced frequency response (EFR) control strategy specifically for energy storage installations to assist reduce this (ESSs). This study suggests a control system that permits the administration of each ESS's state of charge while also enabling the delivery of EFR services from a multi-electrical ESS (SOC).To keep the SOC of each ESS as close to the target SOC while providing EFR, the proposed control system employs a fuzzy logic controller. Both transient and steady-state domains are used to validate the

proposed controller's performance. The advantages of using the suggested controller to manage the SOC of energy storage assets are highlighted by simulation results. These advantages include a decreased rate of frequency shift and frequency nadir following a loss of generation as well as an improvement in the service performance metric, which boosts the service provider's financial gains.

[3] Canan Acar, "A comprehensive evaluation of energy storage options for better sustainability" 2018

There have been a lot of research and development studies in the literature focused on alternative and clean energy resources and systems because of the rising global energy demand and the finite nature of fossil fuel reserves. When addressing important energy challenges like climate change and energy security, renewables are an excellent option. Renewable energy sources must, however, be stored in methods that are reasonably priced, dependable, adaptable, clean, safe, and efficient because their supplies are intermittent and discontinuous. Energy storage is consequently turning into a vital step in developing cutting-edge energy systems for a sustainable future.There are many different methods that energy can be stored, including electrical, chemical, electrochemical, thermal, electromagnetic, and others (such as hydrogen). Each form is made up of various technologies, some of which have already achieved commercial maturity while others are still in the early stages of research and development.

[4] Ning Zheng and R. A. Wirtz, "METHODOLOGY FOR DESIGNING A HYBRID THERMAL ENERGY STORAGE HEAT SINK" 2000

A heat sink design thermal response model for hybrid thermal energy storage (TES) is created. Performance of the heat sink is measured using the stabilisation time and maximum operational (hot side) temperature-to-transition temperature differential. Investigated are the thermal characteristics of the PCM used in the design. The TES-hybrid heat sink's athermal performance model was being integrated with a design optimization algorithm to get the best design possible given the restrictions of geometry and heat loading. This best design is used to build a prototype, which is then utilised to evaluate the performance model. The observed performance agrees with the performance forecasts made by the simulation model.

[5] Nils Hoivik1, Christopher Greiner, Eva Bellido Tirado, Juan Barragan, Pål Bergan, Geir Skeie, Pablo Blanco and Nicolas Calvet, " Demonstration of EnergyNest Thermal Energy Storage (TES) Technology" 2016

The EnergyNest 2 x 500 kWh thermal energy storage (TES) pilot system installed at the Masdar Institute of Science & Technology Solar Platform provides experimental data in this study. To confirm the stability and effectiveness of the TES, measured data are displayed and compared to simulation using a specially created computer programme. The TES is built around a solid-state concrete storage medium called Heatcrete® that has cast-in steel tube heat exchangers. Together with Heidelberg Cement, a special concrete mix for the TES was created;This substance is chemically stable up to 450 °C and has a substantially better thermal conductivity than ordinary concrete, indicating very efficient heat transfer. The EnergyNest concrete-based TES's operational viability is proved by the fact that its measured and demonstrated performance is consistent with simulation-based expectations. A second case study is examined, comparing two-tank indirect molten salt technology to the large-scale TES system discussed in this article.

RESEARCH METHODOLOGY

Magnetite (Fe_3O_4) was prepared using a co-precipitation method. For most of the magnetite discussed in this chapter, 10 nm magnetite was synthesized using $FeCl_3$ and $FeCl_2$ precursors and a base in an inert atmosphere. This is followed by centrifuging and washing the product until the pH is neutral and then drying under a vacuum. Characterization for this material consisted of powder x-ray diffraction. Vanadium oxide (VO_2) was synthesized using a hydrothermal method with vanadium pentoxide and oxalic acid for a certain time.

1. Governing equations

These presumptions are used for the generic simulation:

- A single phase fluid has totally saturated the formation;
- The homogeneous and isotropic nature of the formation;
- Pores have a constant porosity and cannot be compressed or expanded;

2. **Generic reservoir model**

The numerical simulations make use of a general reservoir formation constrained by low permeability caprock (such as shale) at the top and bottom, as shown in Fig. 2. As a preliminary analysis reveals that the heat front in the caprock does not exceed 50 m during ten years of operation, which is the maximum time considered in this work, we fix the caprock with 50 m thickness.

Table. Modelling parameters with uncertain/fixed values were used for the simulations.

Parameters	Symbol	Units	Values	
			Reservoir	Caprock
Permeability	***K***	***m²***	10^{-15} - 10^{-11}	10^{-18}
Porosity	(1)	-	0.01-0.30	0.01
Thermal Conductivity	*A*	W/(111 K)	2.0 -4.0	2.5
Specific Heat	*C*	J/(kg K)	930	1000
Grain Density	*P.*	kg/m³	2650	2500
Formation Thickness	*H*	*m*	*10-100*	50
Well Distance	*D*	*m*	100-200	
Flow Rate	*Q*	kg/s	1-1000	
Inj. Temperature	*T.*	*°C*	100-300	

Analysis

1. **Efficiency of Duty Cycle Round Trip**

- The duty cycle is then applied to the ESS.

- The system is reset to its starting charge at the conclusion of the duty cycle, exactly before the cycle was applied.

2. The Criteria

- The aim was to determine the crucial ESS applications and metrics that needed to be addressed immediately after the purpose and scope were established.
- Peak shaving and frequency regulation were decided upon after considering the opinions of all parties concerned. The emphasis was on electric-only systems, and the metrics considered to be most crucial were noted.

RESEARCH TOOLS

1. Electrochemical Measurement

ORR and OER measurements are done using 0.1M potassium hydroxide in a three-electrode setup (Show in Figure). The Ag/AgCl reference electrode was used along with a platinum coil counter electrode for the experiments. Rotating disk electrode (RDE) measurements were carried out at room temperature using a CHI 1040b potentiostat in a three-electrode system using Ag/AgCl reference electrode and a Pt coil. The working electrode was a glassy carbon (area: 0.2cm2) coated with the catalytic material (see Preparation of the Catalyst). The electrolyte was saturated in oxygen 30 minutes before each rpm scan.

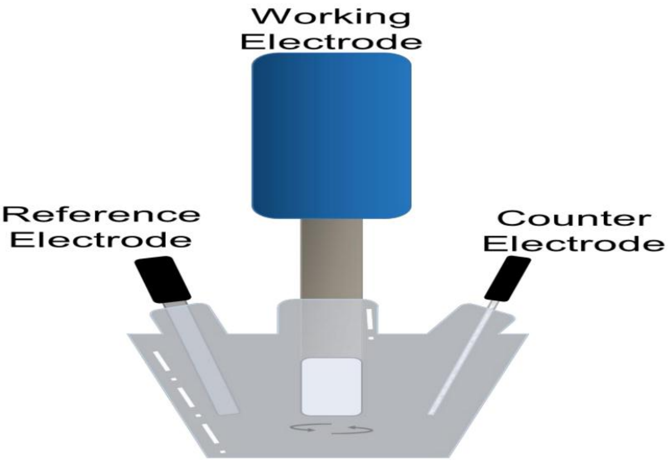

Figure 2. Experimental setup for ORR and OER measurements

2. Zinc-air Battery (ZAB)

A zinc air battery was prepared using a 6:2:2 of metal oxide to pristine carbon nanotubes and annealed carbon tubes with 4ml of ethanol and sonicated for approximately 30 minutes. After 30 minutes, 240uL of Nafion (5wt%) is added and sonicated for another 20 minutes or until the mixture appears homogenous. Toray carbon is then submerged in 0.5mL of the mixture, diluted with 2-3 ml of ethanol, sonicated for 30 minutes, and then dried on a hot plate set to 85C. The mixture is then pipetted onto the Toray carbon while on the hot plate. Loading for samples was 1.5-1.7mg/cm2. Zinc-air setup was built using zinc foil with graphite foil as a cathode with Toray-60 as GDL and anode. Carbon fabric was used as a backing layer and current collector and was compared to a Ni foam current collector. A 6M with 0.2M ZnCl2 was prepared and used as an electrolyte.

CONCLUSION

The following views are supported by the experiences to date in tackling the task given in early 2012 to establish and implement criteria for quickly measuring and communicating the performance of ESS that will be widely accepted and implemented:

Building a critical mass and the credibility necessary to guarantee the end product is accepted in the market requires an open and transparent process where all interested stakeholders can engage at whatever level they think suitable. Contrarily, failing to obtain the necessary and crucial buy-in results from having a single third party carry out a similar endeavour and offer it to interested stakeholders.

The early foundation of a protocol development effort reduces the likelihood that any corporation will make such an effort by putting a stake in the ground. While it may contribute to their initial success in the market, this usually comes at the price of rival businesses in the same field. Furthermore, such development can be expensive; it is best for all parties involved to approach it cooperatively.

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