Monitoring the State of Charge of a Vanadium Redox Flow Battery Using Ultrasonic Sensors: Regular Operation and Degradation Effects

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MOTIVATION

- Monitoring the **state of charge (SoC)** and **state of health (SoH)** is critical for the operational management of a redox flow battery
- SoC and SoH are usually costly to measure and require the consideration of long-term degradation effects
- **Ultrasonic flow sensors** are used to monitor the SoC and SoH of a vanadium redox flow battery

EXPERIMENTAL

Ultrasonic sensor measurements

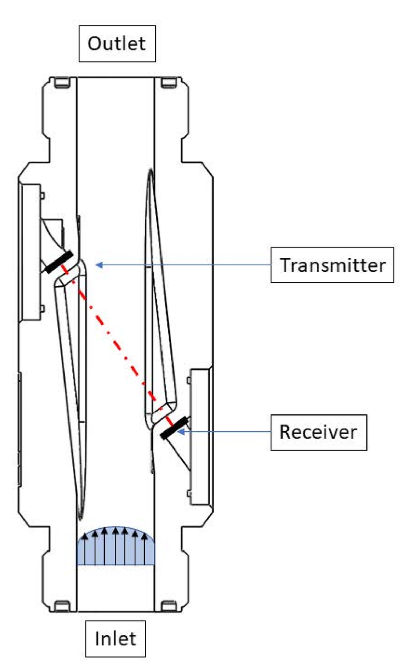
- Speed of sound (SoS)
- Acoustic properties
- Temperature

Scenarios

- Regular operation
- Pre-charge procedure
- High charging rate

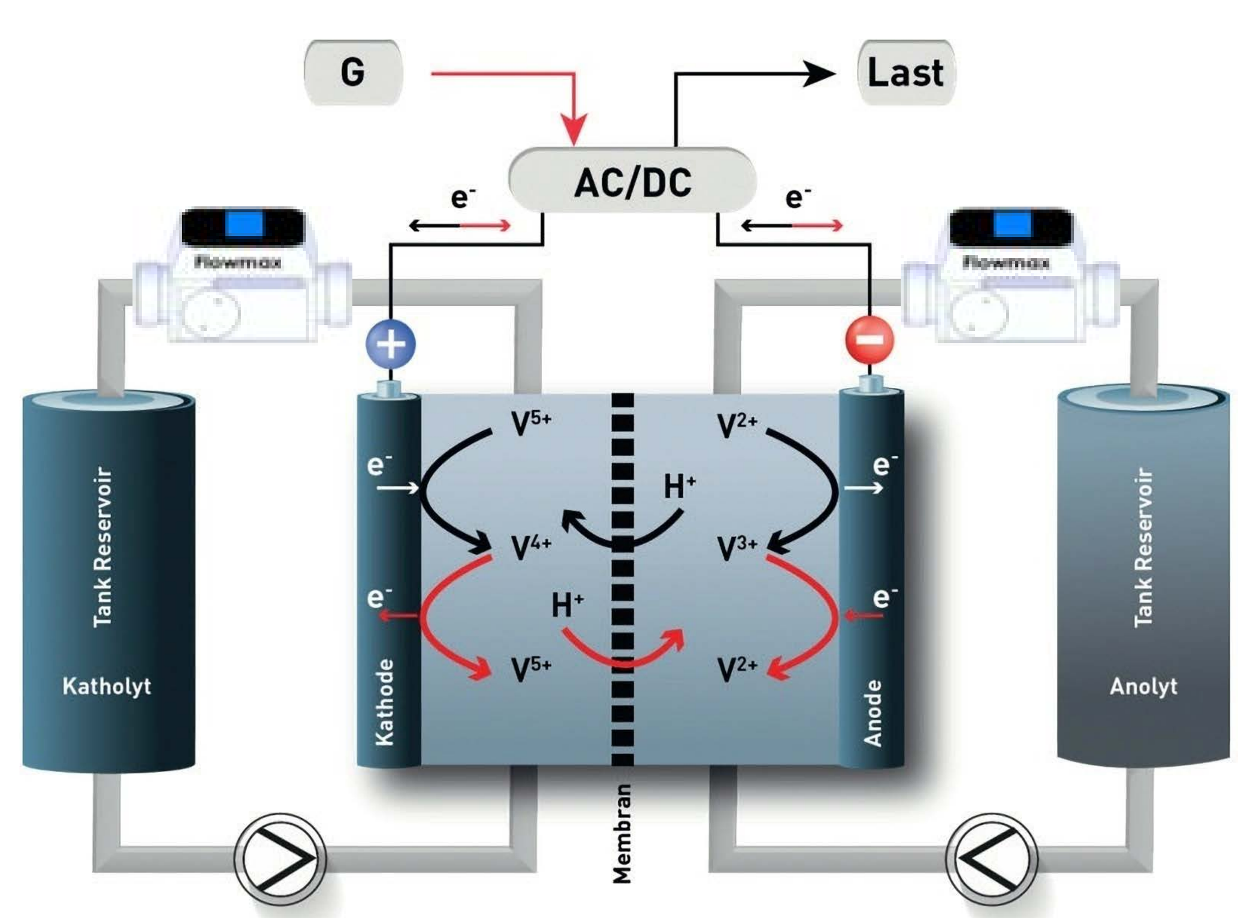
Reference

- Separate measuring cell calculates Open-Circuit-Voltage (OCV)
- Nernst equation used to calculate SoC
- Coulomb Counting used to determine SoH

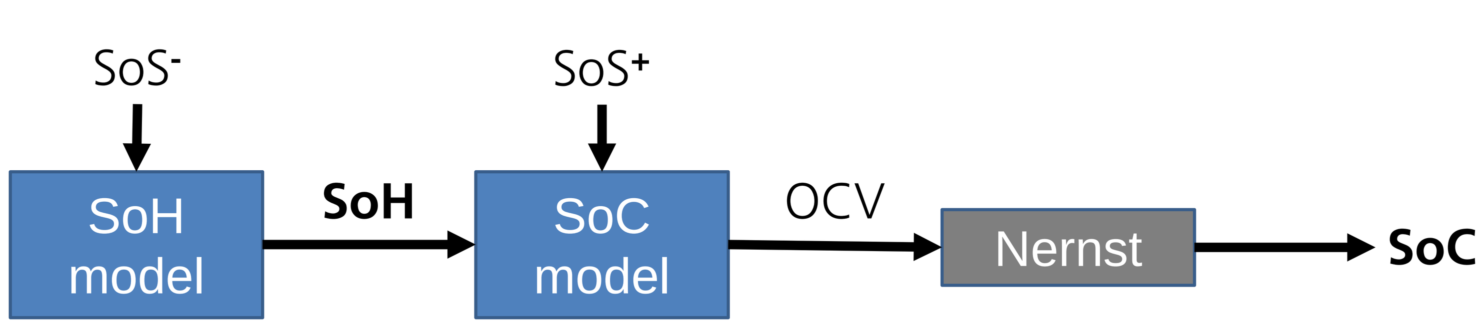
Left: MIB Ultrasonic Flow Sensor
Right: Measuring principle

SCHEME



Scheme of a Vanadium Redox Flow Battery and sensor positions

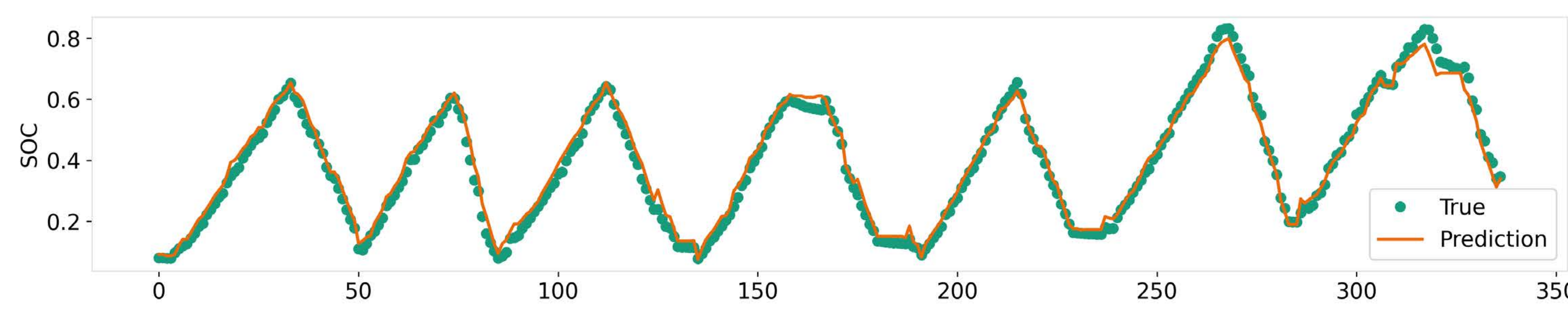
SOC / SOH MODEL



SoS- Speed of sound of negative V^{2+}/V^{3+} electrolyte*
SoS+ Speed of sound of positive V^{4+}/V^{5+} electrolyte*

*adapted by temperature and acoustic properties

REGULAR OPERATION (STEADY SOH)

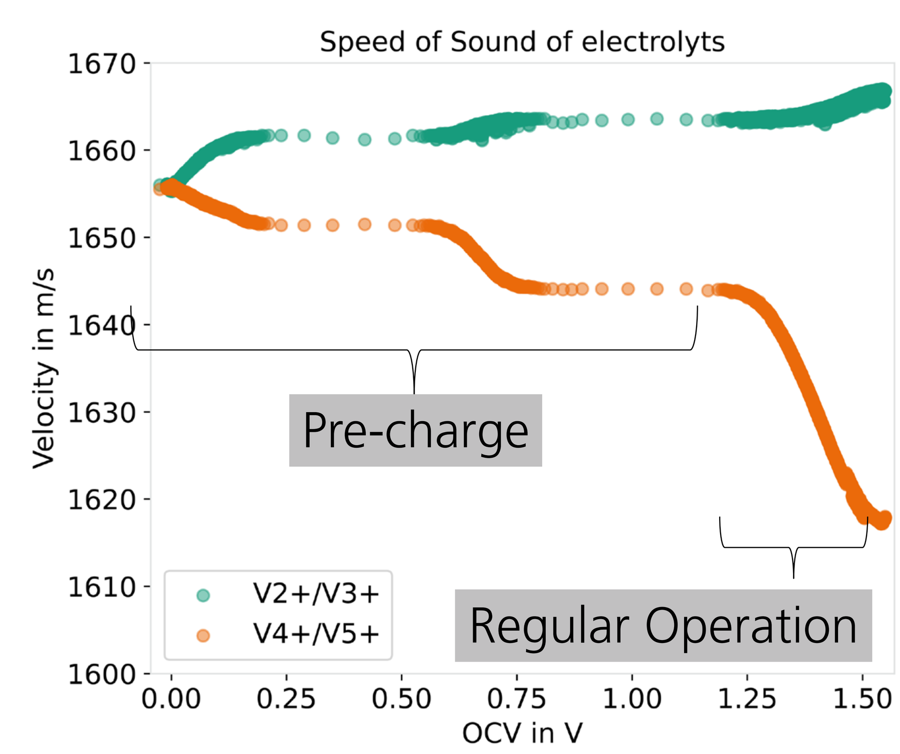


SoC model prediction for steady SoH based on SoS+ (SD=2.3%)

PRE-CHARGE PROCEDURE

- Initially: Both electrolytes have the same speed of sound
- During initial charging: Speed of sound measurements drift apart
- Pre-charge is completed at 1.2V
- Regular operation between 1.26V and 1.56V

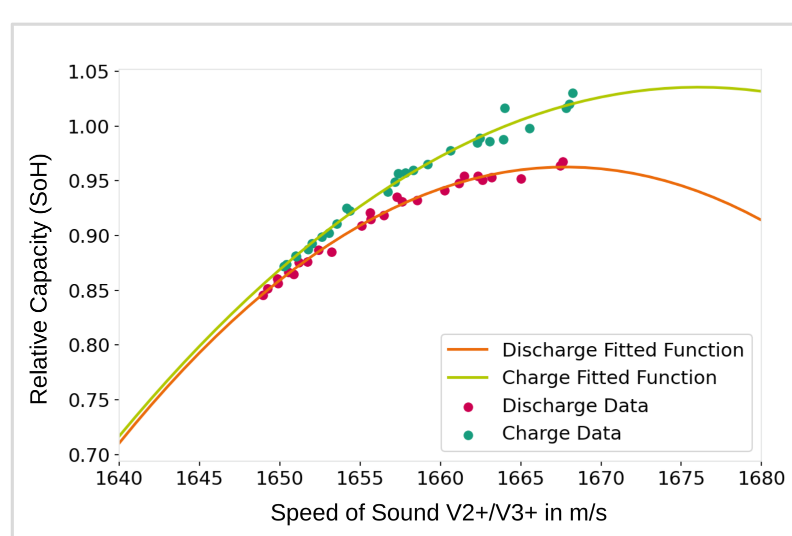
→ **Speed of Sound** provides valuable information for pre-charge procedure



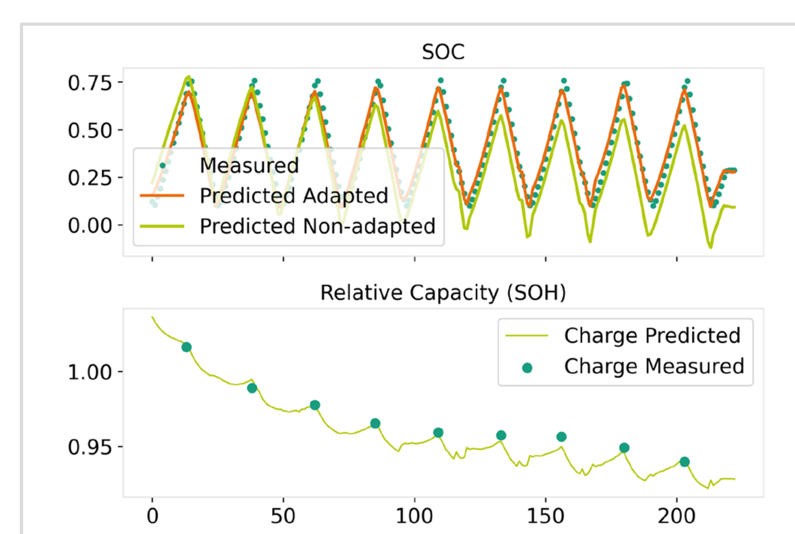
Open-Circuit-Voltage vs. Speed of Sound

HIGH CHARGING RATE (CHANGING SOH)

High currents lead to **crossover effects** and recoverable **loss of capacity**



Ultrasonic measurements of **negative electrolyte** give information about the relative capacity



Not taking the SoH into account leads to flawed SoC predictions → **SoH-adapted SoC prediction** performs better

→ **Properties of both electrolytes** are useful to predict the SoH and to get valid SoC predictions dependent on the SoH

CONCLUSION

Both **SoC** and **SoH** can be monitored by **ultrasonic sensors,** even for non-regular scenarios . While the **negative electrolyte** provides information about the SoH, the SoC estimation is dependable on the SoH itself and the ultrasonic properties of the **positive electrolyte**. An application for other types of redox flow batteries is conceivable.

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