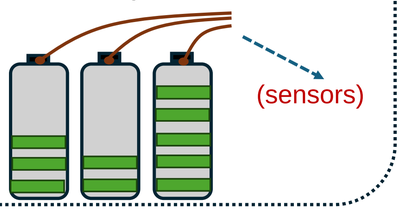
Estimation of Battery Temperature through Impedance Measurements and Novel Application of DRT- A Sensor-less Approach

Danial Sarwar*, Oliver Curnick, Tazdin Amietszajew

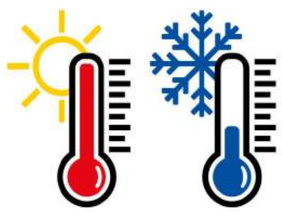
Introduction

Conventional

- Large number of thermocouples
  - Added weight, intricate wiring
  - Surface-only data



Battery Temperature Monitoring



Proposed

- ✓ EIS: Electrochemical impedance spectroscopy to infer battery temperature.
- ✓ Deconvolution of EIS as Distribution of relaxation times (DRT)- A model-free approach.

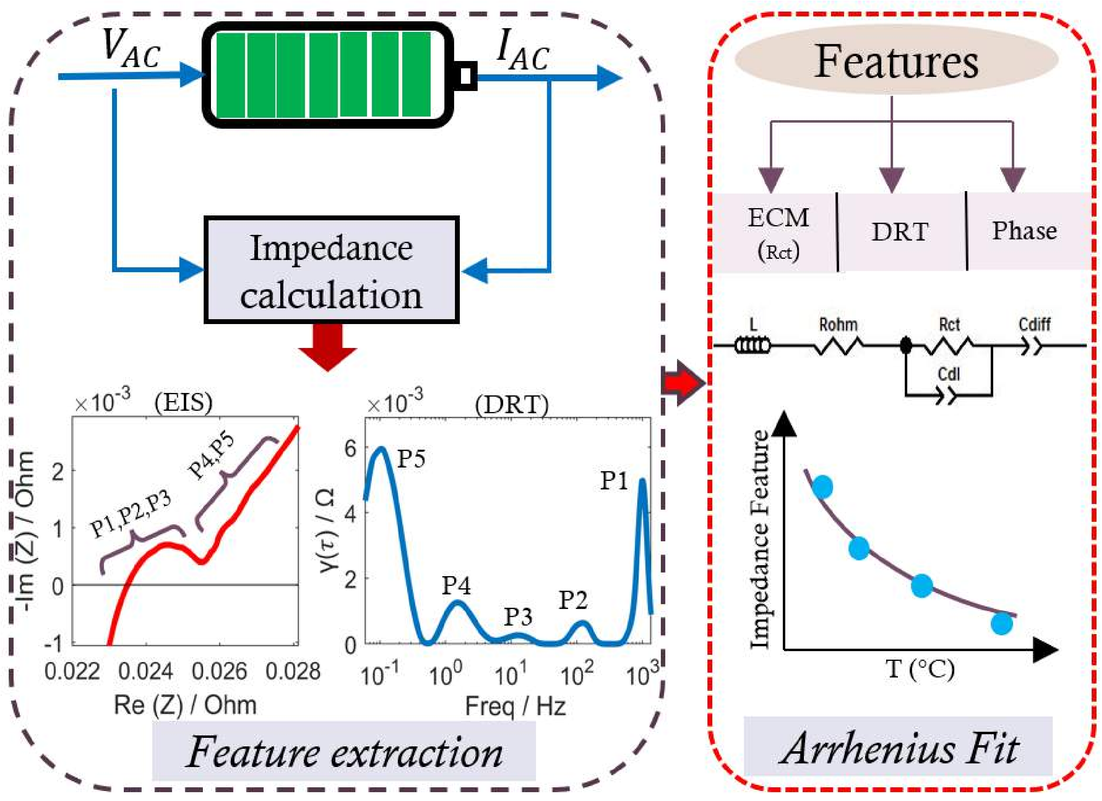
Methodology

❑ Relationship between internal reaction rates and corresponding temperatures, as described by Arrhenius equation.

$$Rate\ constant = A.e^{-E_a/K_bT}$$

(where, A is pre-exponential factor, E_a is activation energy, K_b is Boltzmann constant and T is temperature).

❑ EIS performed at multiple SOCs (state of charge) and temperatures (i) Cylindrical (high energy), (ii) Pouch (high Power). Three features extracted from impedance data i.e., EIS data interpretation using ECM (Equivalent circuit model), DRT and phase shift (φ).

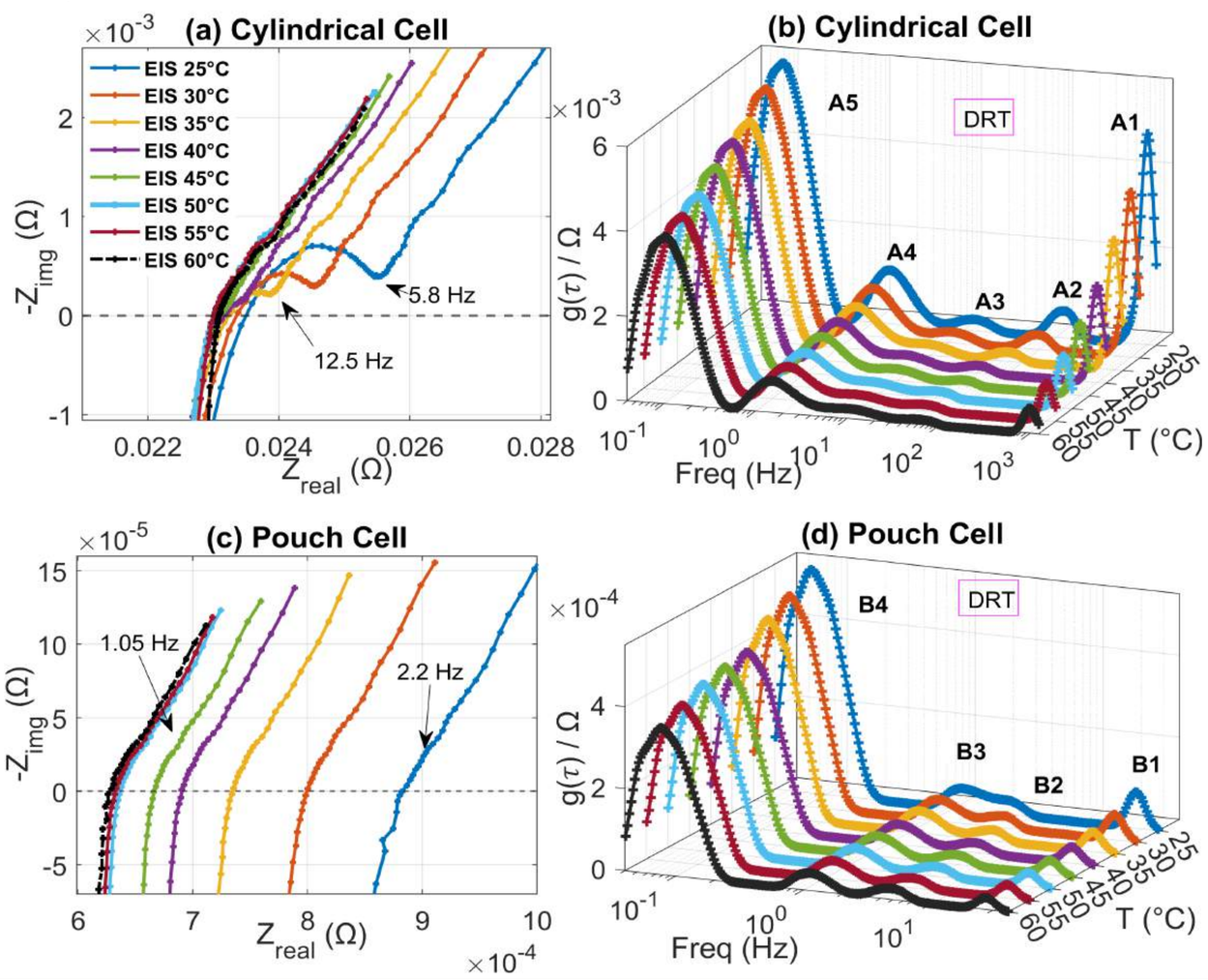


Results

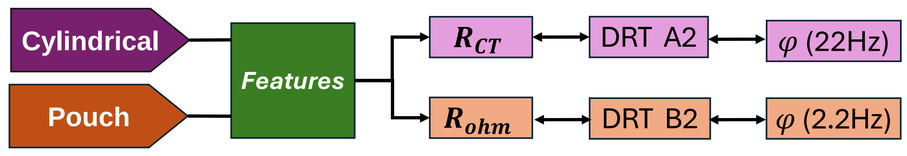
❑ **Cylindrical cells:** Mid-semicircle (charge transfer) diminishes with increasing temperature.

❑ **Pouch cells:** Effect not visible due to low-impedance.

❑ **EIS challenge:** Overlapping processes- DRT improves visualization with distinct peaks at respective time constants

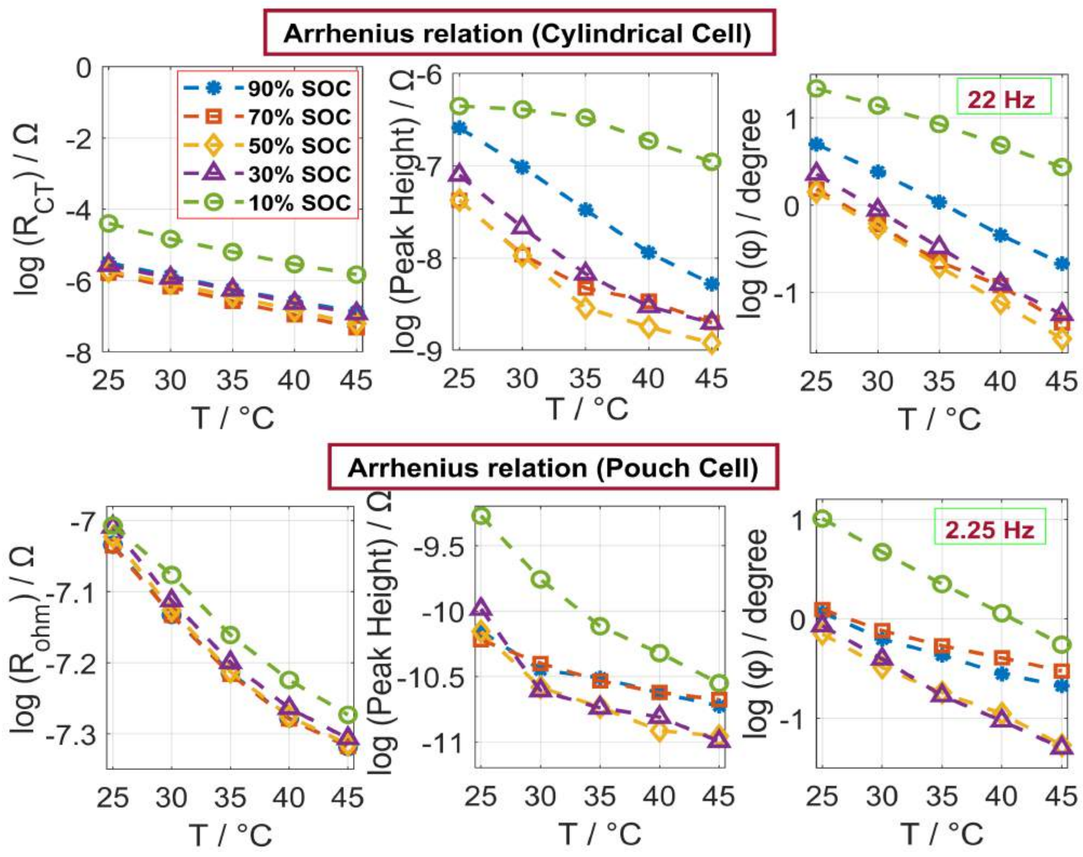


Model based on Arrhenius relation



❑ **Model:** 1st order polynomial, $R^2 > 0.9$

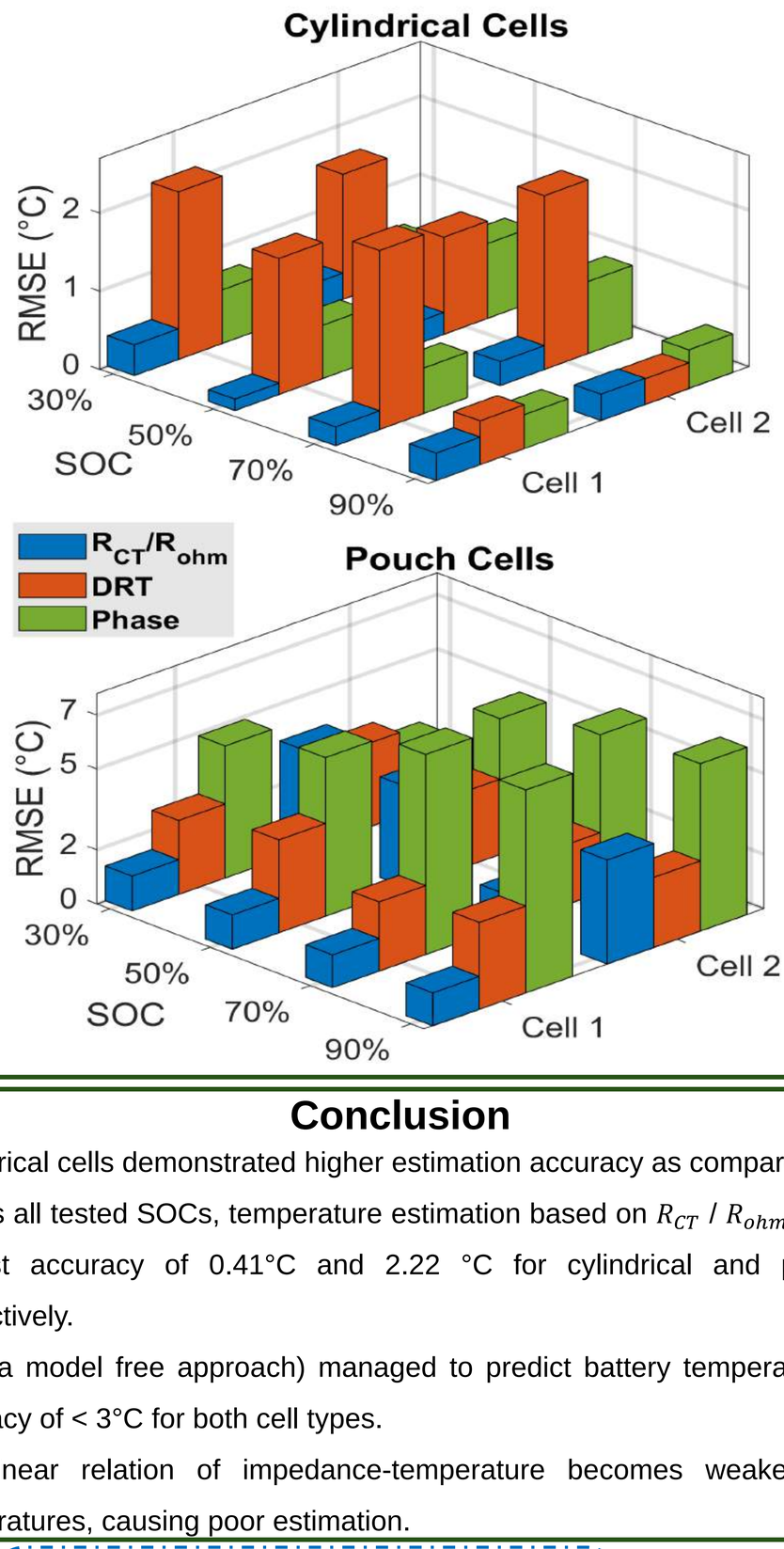
❑ **Temperature correlation**: Strong; minimal SOC impact



Model Validation

❑ **Cylindrical cells:** R_{CT} (error 0.84°C), DRT peak (2.25°C), φ (1.19°C)

❑ **Pouch cells:** R_{ohm} (2.5°C), DRT peak (3°C), φ (6.8°C)



Conclusion

❑ Cylindrical cells demonstrated higher estimation accuracy as compared to pouch.

❑ Across all tested SOCs, temperature estimation based on R_{CT} / R_{ohm} showed the highest accuracy of 0.41°C and 2.22 °C for cylindrical and pouch cells, respectively.

❑ DRT (a model free approach) managed to predict battery temperature with an accuracy of < 3°C for both cell types.

❑ The linear relation of impedance-temperature becomes weaker at higher temperatures, causing poor estimation.

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Contact Details

Danial Sarwar, PhD

Research Fellow

C-ALPS, Coventry University

danial.sarwar@coventry.ac.uk

Coventry University