Thermal Management of Lithium-Ion Batteries for Stationary Energy Storage: Ageing, Modelling, and Cooling Strategies

Reliable lithium-ion cell storage is essential for renewable microgrids, but safety, lifetime and cost depend on how the cells are cooled. This thesis examines how thermal gradients shape the performance, ageing and economics of mixed-age, immersion-cooled battery modules for a rural school microgrid. Experimental resistance characterisation of NCR18650B cells supported a validated three-dimensional thermal model, which was extended to module-scale computational fluid dynamics using measured microgrid loads. Gradient-controlled ageing experiments, a physics-guided CNN-LSTM voltage predictor, vortex-generator design studies and a degradation-informed techno-economic analysis followed. Simulations showed that dielectric immersion reduced inter-cell temperature spread from about 20 °C under air cooling to 3–5 °C. Experiments on single cells showed ageing was non-monotonic, with moderate gradients most damaging, and the predictor achieved 0.037 V mean error. Suggested vortex generators in the module lowered downstream temperature differences by over 5°C. Uniform immersion extended experimental life to the 80% health threshold from about 200 to 500 cycles, improving project economics. Together, these integrated studies link thermal physics, degradation, prediction and cost within one framework for second-life stationary storage.

Keywords: Electrothermal cell modelling; Immersion-cooled lithium-ion modules; Thermal gradients and ageing; Physics-guided deep learning; Vortex-generator flow control, Remote grid technoeconomics