A dual-head temporal convolutional network approach for cloud-based battery state-of-health prognostics in a digital twin

Dr. Georg Roeder[1], Dr. Martin Schellenberger[1], Dr. Richard Julian Tolchard[2], Mr. Samppa Jenu[3], Dr. Fride Vullum-Bruer[4], Mr. Rambabu Kandepu[5], Prof. Dr. Vincent R. H. Lorentz[1]
[1]Fraunhofer IISB, , Germany, [2] SINTEF Industry, , Norway, [3]VTT Technical Research Centre, , Finnland, [4]SINTEF Energy Research, , Norway, [5]Corvus Energy, , Norway
Accurate State-of-Health (SoH) prediction is critical for reliable battery management systems (BMS) and their digital twins. Within the Horizon Europe project BATMAX, a cloud-based digital twin framework is being developed, integrating experimental and operational data with physics-based, data-driven, and hybrid models for advanced BMS. A central requirement is a data-driven SoH prognostic model achieving prediction errors well below a user-specified threshold of 3 % and suitable for cloud deployment.

This work presents a Temporal Convolutional Network (TCN) with a dual-head output architecture for capacity-based SoH estimation of lithium nickel manganese cobalt oxide (NMC) batteries. Training and validation utilize cycling datasets from multiple cycling test sites, covering diverse state-of-charge windows and a representative maritime load profile. The TCN's hyperparameters are adjusted via Bayesian optimization. The dual-head design features feed two parallel output heads: one predicts absolute SoH, the other predicts the incremental SoH degradation (ΔSoH). A composite loss function balances absolute accuracy with degradation-trend consistency, emphasizing the absolute SoH head and using the ΔSoH head as an implicit regularizer.

Testing on held-out data subsets across different SoC windows yields root-mean-square and maximum absolute errors of 1 %. This meets maritime end-user accuracy specifications, and the model is transferable for integration into a cloud digital twin. Ongoing investigations aim to achieve comparable SoH prediction accuracy using only instantaneously measured variables, voltage, current, temperature, and features derived thereof eliminating the need for persistent storage of accumulated quantities in operational deployment.