Zentrum für Sonnenenergie- und Wasserstoff-
Forschung Baden-Württemberg

Machine Learning Methods for Automated Fuel Cell Monitoring

Lukas Klass, Alexander Kabza, Katharina Strecker, Frank Sehnke, Markus Hölzle
Helmholtzstr. 8, 89081 Ulm, Germany
phone: +49 731 9530-824, e-mail: lukas.klass@zsw-bw.de

Introduction

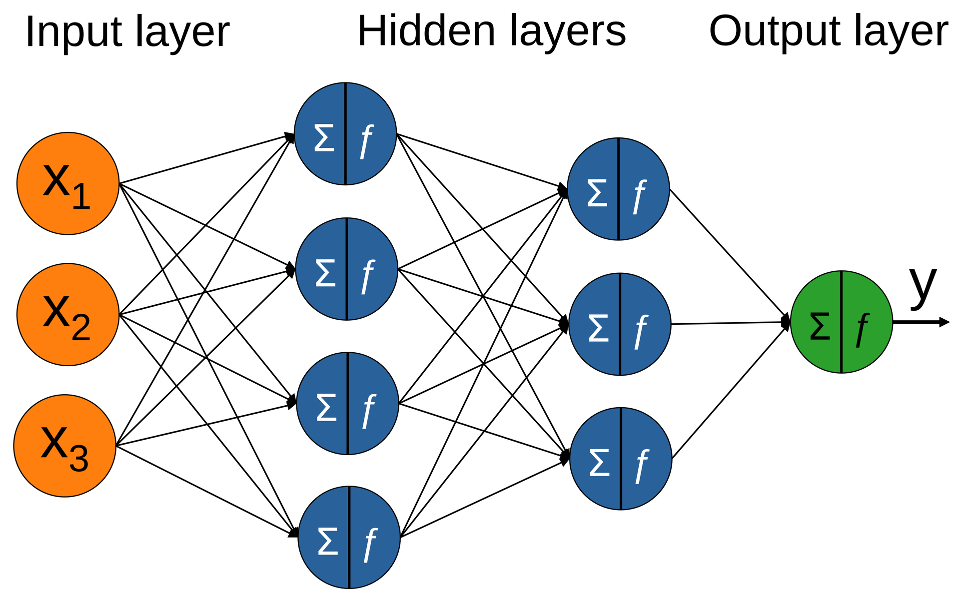
- Fuel cells on test stations are monitored using constant alarm thresholds
- Detection of errors with little or delayed impact on the fuel cell's performance is impossible due to widespread operation range
- Too sensitive alarm thresholds may interrupt tests, especially during transient operation

Objective

- Development of machine learning based approaches to monitor the operation and testing of fuel cells stacks on test stations

Approach

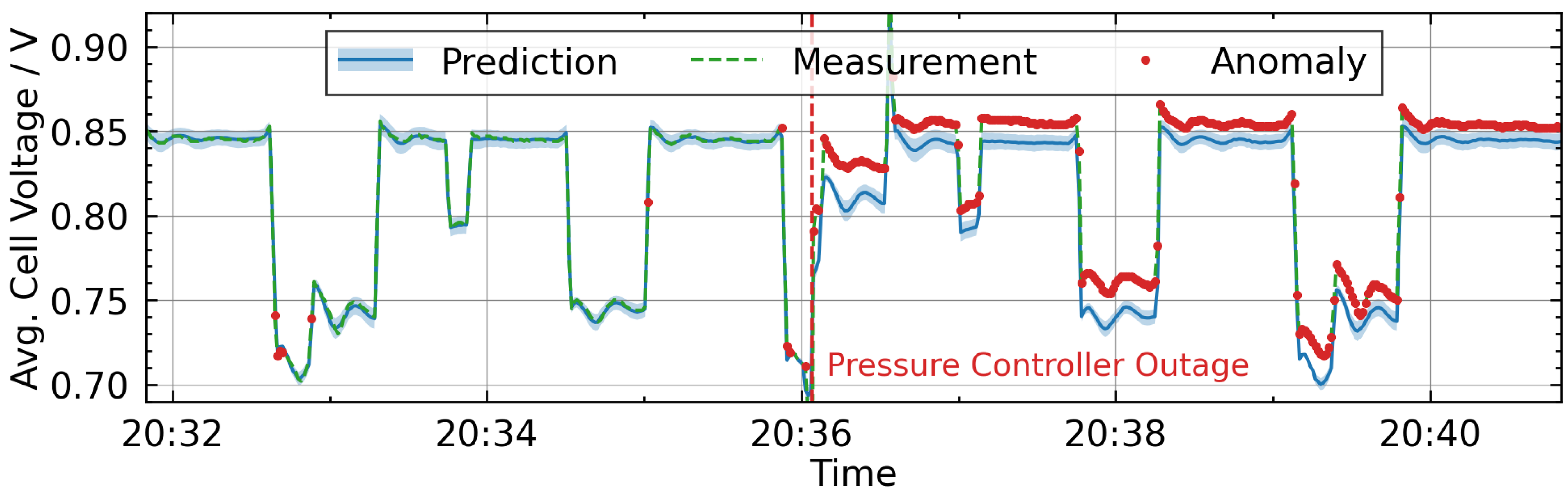
- An Artificial Feed Forward Neural Network (FF-NN) as shown on the right is trained as a fuel cell model to predict the stack's cell voltage based on current, stoichiometry, anode & cathode gas temperature & pressure, dew point, coolant flow & temperature
- A second FF-NN is trained as an error model (assuming a Gaussian error) to estimate the fuel cell model's prediction confidence using the same input parameters
- The deviation of the predicted and the measured cell voltage in relation to the confidence is a probabilistic indicator for anomalies in the measurement



Architecture of a Feed Forward Neural Network

Short Term Prediction

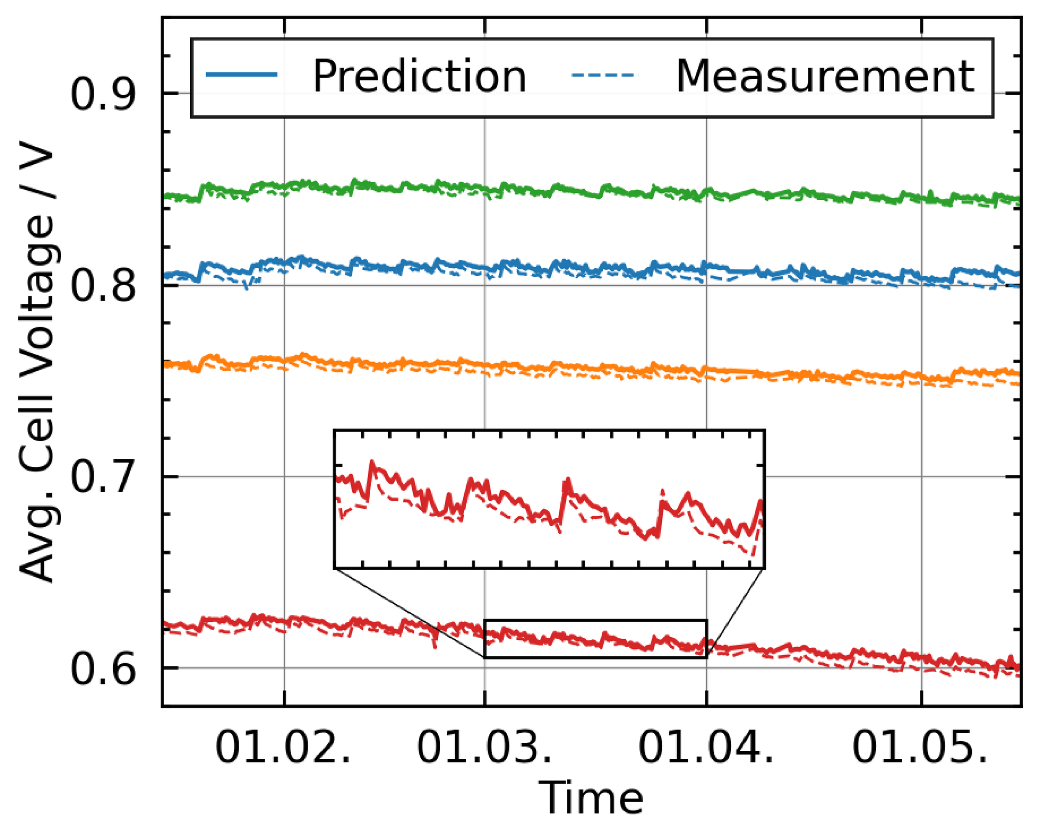
- Anomaly (prediction vs. measurement) due to a temporary pressure controller outage causing a cathode starvation
- 3 h training data, 2.5 mV RMS error
- Anomaly detected with 99.99% confidence
- Singular False-positives on transients



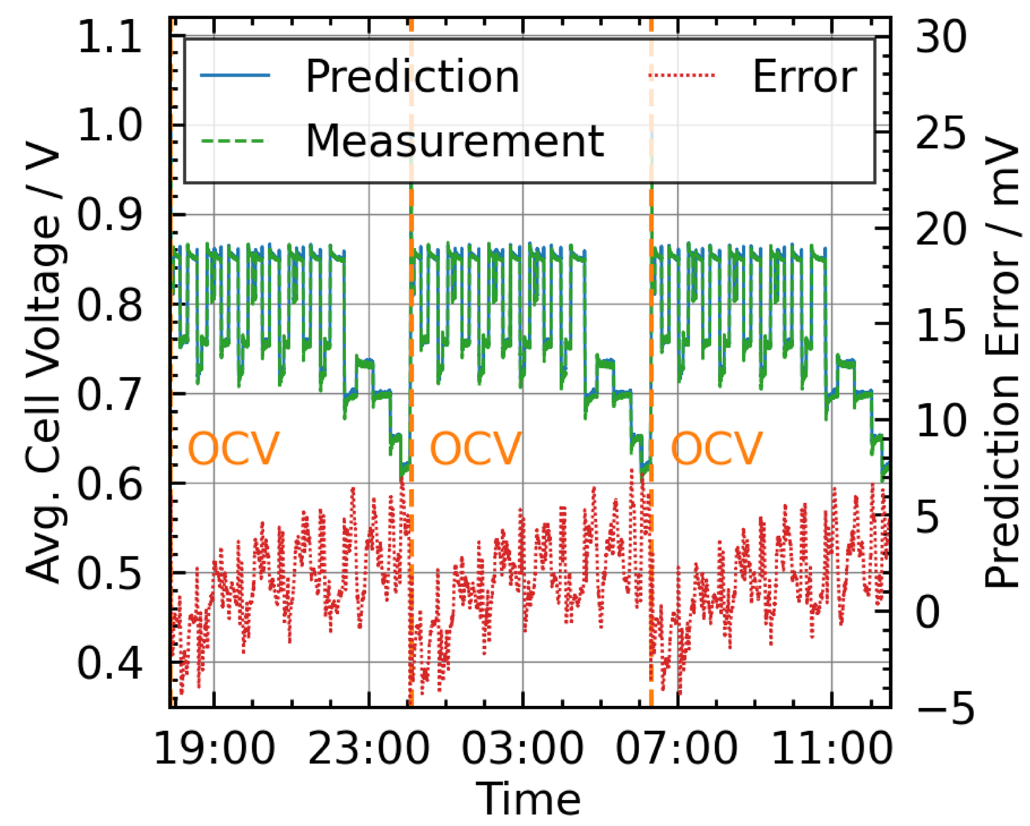
Detection of a Cathode Pressure Controller Outage

Long Term Prediction

- Additional input features: Operating time, time since last restart and operation point dwell time
- 4300 h training data, 8.4 mV RMS error
- Accurate prediction of reversible and irreversible cell voltage degradation (saw tooth profile in the left plot)
- OCV-recovery is not captured yet (change of error in the right plot)



Long Term Prediction of four different Operation Points



Prediction Accuracy of a Load Cycle

Conclusion

- During fuel cell stack testing, FF-N are able to detect errors which were undiscovered with conventional threshold monitoring
- The model must be able to capture four different time scales: overall irreversible degradation, recovery after shutdown, settling time after change of operating conditions and controller oscillations
- FF-NN is able to model time scales if they are parametrized as features, consequently FF-NN must be enabled to learn which events have to be remembered

Outlook

- Introduction of local history as feature
- Investigation of Long Short-Term Memory Neural Networks (WIP)
- Application of clustering methods to monitor operating conditions
- Development of an automated monitoring-framework

ZSW November 21