Box-Jenkins Autoregressive Models for PEMFC Operating on Dynamical Conditions

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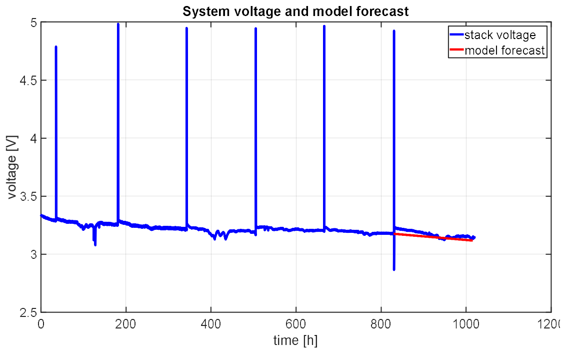
Proton-exchange membrane fuel cells (PEMFCs) are promising alternatives to internal combustion engines in long distance high payload transport applications. Nevertheless, the problem of short cell durability must still be addressed. The current U.S. Department of Energy ultimate target for stack system useful life in automotive application is 8000 hours. Model-based control is being investigated for solving the durability problem through appropriate control of the operating conditions which are known to affect fuel cell integrity. However, the construction of appropriate PEMFC models for such control scheme is no trivial task due to the need of several specific test for fitting a large number of parameters. The purpose of this study is to estimate and validate autoregressive models, obtained from input-output signals, as a less computationally expensive and faster to estimate alternative to mechanistic models.

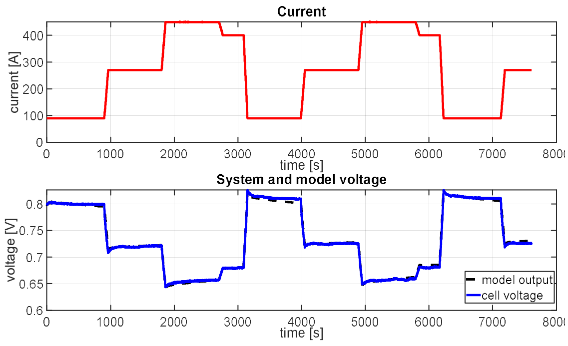
Data from four experiments, in static and dynamic regime are used to estimate and validate the models. Each dataset is divided into estimation and forecasting subsets and a Box-Jenkins system identification methodology is applied [1]. Time series stationarity condition, as well as model order and structure, are defined through analysis of correlation and partial autocorrelation functions of each output signal. Coefficients are estimated by Yule-Walker equations. Validation is performed by comparing model output with experimental data and the model is used to forecast future system output.

For static operation, an Auto-Regressive Integrated Moving Average model of orders 1 (ARIMA[1,1,1]) is able to approximate the output and forecast future mean voltage. The ARIMA model structure deals with the non-stationary characteristic of the signal and, being purely autoregressive, is estimated just through voltage signal. In the case of dynamical regime, a Box-Jenkins Transfer Function model is found most appropriate to capture the dynamic in voltage (output) as a function of cell temperature and current (inputs).

The models are validated in two ways: analysis of the correlation of residuals through the Box-Ljung test and calculation of the root mean squared error (RMSE).



a) Static voltage profile and model forecast



b)Top: cell current. Bottom: cell output voltage and model approximation.

Keywords: PEMFC modelling, autoregressive models, system identification.

1. Box, G.E.; Jenkins, G.M.; Reinsel, G.C.; Time Series Analysis, Forecasting and Control 4th ed.; John Wiley & Sons, Inc.; New York, NY, USA, 2008.