Nonlinear Data-driven Identification of a Thermo-electric System

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1 Introduction and motivation

Thermo-electric coolers based on the Peltier effect are a popular actuation option in high-precision systems where active heat exchanges are required [1]. State-of-the-art modelling in the field is largely performed by relying on first principles. This contribution presents a data-driven approach to modelling the nonlinear dynamics of Peltier elements.

2 Identification procedure

The adopted identification methodology proceeds in two steps. Firstly, a nonparametric analysis is achieved in the frequency domain, with the objective of quantifying the amount of nonlinear distortions affecting the system output spectrum at a given excitation amplitude. A discrimination between distortions originating from odd (symmetric) and even (asymmetric) nonlinearities is also made possible by the use of special multisine excitation signals [2]. Secondly, a nonlinear state-space model is identified from data. The identification is carried out in the frequency domain again, by minimising an unweighted least-squares cost function. The nonlinear model terms are function of the measured current at the system input side, following the prior knowledge that a Joule effect, which is related to dissipation in heat conduction, is the dominant source of nonlinearity in a Peltier element dynamics when excited over a reasonably small temperature range.

3 Identification results

Fig. 1 depicts the nonparametric analysis of an input-output data set measured under a multisine excitation signal with a root-mean-squared amplitude of 0.64 A. In the frequency domain, this signal contains no power at the even lines to detect asymmetric nonlinearities, and randomly leaves odd lines unexcited to detect symmetric nonlinearities. Fig. 1 reveals that a substantial even nonlinearity (blue) distorts the system output spectrum (grey), as opposed to the marginal amplitudes of the odd distortions (yellow) and noise disturbances (black). The result of the nonlinear state-space modelling step is provided in Fig. 2. The identified model incorporates a quadratic input term in the state equation, reflecting the outcome of the nonparametric analysis in Fig. 1. This model features 5 state variables and overall comprises 41 parameters. The associated residual in Fig. 2 (green) is seen to be 10 to 20 dB below the corresponding linear modelling error level (blue) over the frequency range from DC to 0.1 Hz.

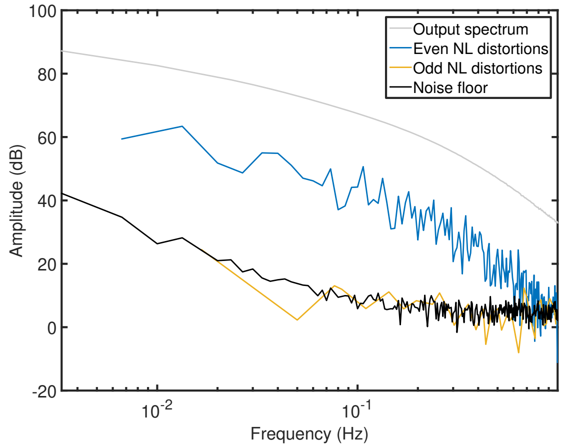

Figure 1: Nonparametric analysis of test data.

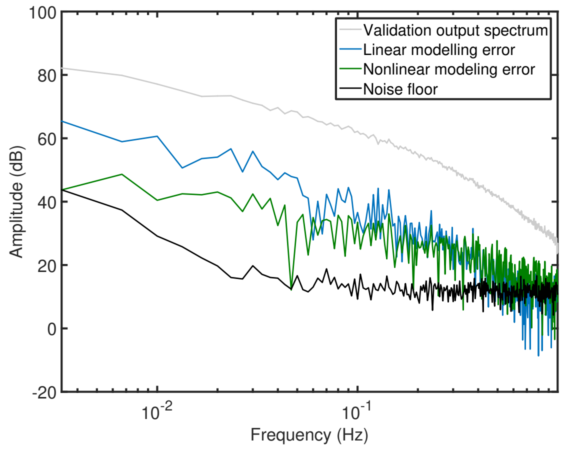

Figure 2: Parametric nonlinear modelling in state space.

4 Conclusion and outlook

On-going investigations focus on identifying the Peltier dynamics over larger temperature ranges, and on exploiting the resulting data-driven models for designing feedback linearisation controllers.

References

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[2] J. Schoukens, L. Ljung, *Nonlinear system identification: a user-oriented road map*, IEEE Control Systems Magazine 39(6), 28-99, 2019.