Silesian University of Technology

Faculty of Automatic Control, Electronics and Computer Science

Department of Automatic Control and Robotics

Patryk Grelewicz

Application of fusion of chosen control performance assessment methods for automatic diagnostics and performance improvement of control systems

Supervisor:
prof. dr hab. inż. Jacek Czeczot

Co-supervisor:
dr hab. inż., prof. Pol. Śl. Tomasz Kłopot

Gliwice 2022

Abstract

In modern, industrial control systems it is crucial to monitor control performance in continuous manner to detect any degradations. Maintaining control performance at a satisfactory level ensures high energy efficiency, final product quality and lifetime of control equipment with low post-production wastages. Considering Industry 4.0 transformation, control performance assessment (CPA) algorithms are a point of interest for academic and industrial researchers.

This PhD dissertation describes synthesis of CPA system dedicated to industrial, PID closed loop systems based on machine learning (ML) approach. General concept of suggested system is to assess the control performance based on the rejection response of the system to an intentionally applied additive disturbance and compare it with the so-called reference response. For practical application, binary assessment is suggested (OK or NOK) based on degree of difference with reference response. For this purpose, ML classification algorithms were applied. Training and validating datasets consists of feature vector of thirty control performance indices (CPIs) calculated based on the closed loop response data with the final assessment (OK or NOK) as a label. Automatic labelling method was developed, based on frequency-based indices: gain and phase margins supplemented with normalized distance from reference response. Generated datasets were used for training of ML algorithms, achieving high classification accuracy (higher than 95% for selected algorithms). The performance of CPA system was compared with other existing methods and verified based on simulations and experimental studies. For the latter, cloud-based implementation of the CPA system was prepared and it was verified on a real laboratory setup. Both simulation and experimental validation confirm high accuracy of control assessment.

Generated dataset was investigated for potential correlations between CPIs and then, forward feature selection method was used to determine the universal subset of features, reducing the number of thirty to seven features. It drastically decreased computational and memory resources required for CPA system and allowed to prepare PLC-based implementation. General purpose function block was prepared for Siemens S7-1200/1500 PLC, implemented in TIA Portal software. It consists of several functionalities, i.e. process model identification, CPIs calculations and classification of control performance. Its operation has been verified on real laboratory setup and again, obtained results indicate high accuracy of performance assessment.

In conclusion, suggested CPA system ensures high accuracy of performance assessment for considered class of closed loop systems. Thus, the following thesis statement was confirmed: *the developed CPA system can explicitly assess control performance based on load disturbance rejection response data for closed loop systems in process automation, while clearly and objectively considering the predefined assumptions and limitations*.