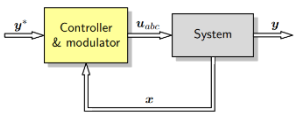
Predictive Control of Power Electronics Systems

Summer School 5 – 9 June 2023 at ETH Zurich, Switzerland

This course focuses on model predictive control (MPC) methods that fully exploit the performance potential of power converters by ensuring fast control during transients and superior steady-state operation in terms of harmonic distortions and system losses. Such MPC methods are particularly suitable when operating at low pulse numbers, such as high power electronics and traction converters, or when considering complicated systems such as converter systems with sine filters or modular multilevel converters. MPC addresses switched nonlinear systems, constraints, and systems with multiple inputs and outputs.

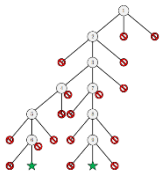
The objective of the course is to bridge the gap between modern control theory and power electronics systems and applications. To this end the main MPC methods available today for power electronics systems are introduced, including control methods without and with a pulse width modulator. An emphasis is put on computational methods to solve the underlying (integer) optimization problems.



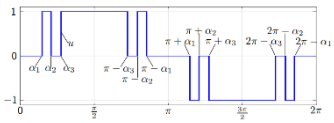
The target audience are power electronics students with an interest in control methods, as well as control students who would like to better understand how, based on control theory, existing control algorithms can be adapted, and new control algorithms can be developed to tackle challenging applications.

Content:
The 8th edition of this lecture is offered as a 40-hour block course consisting of 10 blocks with lectures and exercises alternating:

- Review of high power electronics systems (three-phase systems, induction machines, semiconductors, multilevel converters, electrical grid) and derivation of their state-space models.
- Review of classic control and modulation methods. Review of pulse width modulation (PWM), including carrier-based PWM, optimized pulse patterns and their computation.
- Direct MPC with reference tracking, in which the controller directly manipulates the switch positions. Formulation of the current control problem with reference tracking, enumeration technique to solve the short-horizon problem, generalization of the control problem to long prediction horizons, and branch and bound optimization techniques. Application to multilevel inverter drive systems, and extension to inverters with LC filters.



- MPC with optimized pulse patterns (OPPs), in which the time instants of the switching transitions are manipulated. Characteristics of OPPs, techniques to compute OPPs offline, formulation of a fast closed-loop controller, methods to solve the underlying quadratic programming problem and application to multilevel inverter drive systems.



- MPC using PWM. Formulation of the MPC problem, imposition of hard and soft constraints, techniques to solve the quadratic program in real time, application to neutral point clamped converters and modular multilevel converters.
- Summary of the course, and outline of recent research results and activities.

Exercises based on industrial power electronics systems are used to consolidate the presented control concepts and to assist the learning process. Matlab/Simulink simulations further improve the understanding of the control methods, their benefits and intrinsic challenges.

Practicalities:

- Time and date: From 8:00 until 17:00, from Monday to Friday in the week 5 – 9 June 2023
- Location: ETZ building, ETH Zurich, Switzerland
- Language: English
- Lecturer: Dr. Tobias Geyer, ABB System Drives, t.geyer@ieee.org
- The summer school is free of charge, but registration by email is required (t.geyer@ieee.org)

Details:

- The following material is included: Lecture notes based on a book, slides and Matlab/Simulink exercises with solutions.
- Not included are accommodation, lunch and coffee breaks, cost of travel, a dedicated ETH login (but eduroam works), and credit points for the course
- Consider bringing your own laptop, ensure that you meet the travel requirements for Switzerland (e.g. a valid tourist visa as applicable)
- Course details are available on Course Catalogue - ETH Zurich
- Prerequisites: Power electronic (systems) and control systems