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Abstract

Analysis of predictive control algorithms for induction motor drives

by

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In the dissertation problems related to predictive control of inverter-fed motor drives with induction motors are investigated. In particular, the possibility of using algorithms with continuous and finite sets of solutions for adjusting selected state variables is analyzed. The influence of particular design parameters of the developed structures on the quality of the control was described and presented. The content of the thesis is described below.

The dissertation consists of seven chapters supplemented by a bibliography and three appendices.

The first chapter provides an introduction and overview of the literature in the field of predictive control and induction motor drive systems. It also formulates objectives, thesis and scope of the work.

The second chapter presents the evolution of predictive algorithms, and the breakdown of such systems into generations is discussed. The directions of development of this type of solutions are pointed out, including algorithms based on hysteresis, and the trajectory model. The next part of this chapter details the problem of predictive control in a discrete state space and discusses the classification of such algorithms, highlighting the division due to the considered set of solutions, horizon length and way to solve the optimization problem. Next the issues of sustainability, feasibility and predictive computational complexity of algorithms are discussed.

The third chapter presents the mathematical models of research facilities, including the induction motor, inverter and systems with elastic joint. The classic structure of the field-oriented control DFOC is also discussed.

Chapter four presents the constituents of the experimental research station. The station consists of two inductive motors, two inverters, measuring circuits, platform of rapid prototyping dSpace and a computer.

Chapter five presents control structures using a predictive algorithm with a continuous control set. Speed and position regulators are presented. They are structurally similar to the field-oriented control system, but all PI regulators are replaced by one prediction controller. During the study analyzed how the quality of regulation depends on the particular design parameters of the controller, including the output and control prediction horizons and the values of the weight matrix elements. The possibility of limiting the computational complexity of the developed regulators was also checked by using methods of reducing areas and methods of searching the set of solutions using binary trees. The last part of the chapter presents selected results of experimental research confirming the correct functioning of the developed control structures.

Chapter six presents predictive control structures using a finite set of solutions that take into account only control vectors available directly (without the modulator) in the inverter. The torque and speed controllers have been developed. As with systems with a continuous set of solutions, the influence of selected regulator design parameters on the quality of regulation was analyzed. In particular, the impact of the prediction horizon, the weighting factors, and the form of the objective function were examined. Due to the time constants and variability of particular variables, as well as some specific features of this type of control, there are a number of problems associated with the use of predictive algorithms with finite sets of solutions for controlling drive systems with induction motors, especially for speed control. This part of the work presents these problems and proposed some algorithmic solutions to avoid the consequences of skipping some aspects during designing the control structure. In particular, in order to ensure correct stabilization of both adjustable variables (stator flux and velocity), it was proposed to scale the weight coefficients of the quadratic objective function based on the speed error. In terms of reducing the torque oscillation in steady state, a system with two control zones was developed. The last part presents selected results of experimental research confirming the results of simulation tests.

The last chapter of the paper presents a summary of the research carried out and an overview of the most important achievements of this work.

In the appendix 1 presents a cascade speed control structure of the drive system with elastic coupling, composed of two prediction controllers : the master speed controller (with a continuous control set CCS-MPC) and a subordinate torque controller (with a finite control set FCS-MPC). In the internal control loop, the controller described in section 6.2 is used. Whereas, the regulator in the outer loop uses a model of two-mass drive system. The chapter presents the results of simulation studies.

In the appendix 2 presents a comparison of predictive speed control structures with finite and continuous set of solutions with the classic field-oriented control structure DFOC.

The Appendix 3 includes the research on sensitivity to the motor parameter changes.

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