Selected topics in the theory of electrical engineering (Wybrane zagadnienia teorii elektrotechniki) - Models of electrical machines

Course authors: Zbigniew Krzemiński, Andrzej Wilk (WEiA)

The course is divided into 2 modules (4 hours for the first module and 11 hours for the second one), covering 15 hours of lectures in total.

The first module, authored by Dr A. Wilk, discusses selected aspects of electromechanical energy conversion by:

1. Introduction to the basic coordinates for the electrical and mechanical systems, conservative and dissipative lumped elements, and coenergy/energy-state functions.
2. Energy-state functions for a system of inductances and a system of capacitances.
3. A restricted form of Lagrange's equation.
4. Degrees of freedom and generalized coordinates.
5. Formulation of equilibrium equations for electromechanical systems – the Euler-Lagrange equation.
6. Electromagnetic forces and torques from the principle of virtual work.
7. Electromagnetic forces and torques from Lagrange's equation.

In the first course module students are learned about Lagrangian formulation of equilibrium equations of electromechanical systems based on energy quantities. At the beginning the basic coordinates for describing lumped electrical and mechanical elements are introduced. The defining-characteristic curves of lumped elements as energy-state and coenergy-state functions are described for conservative elements. The Rayleigh and co-Rayleigh dissipation functions for the lumped dissipative elements are also described. After developing energy-state and coenergy-state

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functions the partial derivatives are analysed in other to form equilibrium equations. Next, a system composed of many inductance elements taking into account self and mutual inductances is considered. Using the energy/coenergy state functions a restricted form of Lagrange's equation is described. Before these state functions are used in Euler-Lagrange's equation a set of generalized coordinates (the number of degrees) must be substituted in Lagrangian function for the original set of coordinates. Relationships between the coordinates is defined in a constraint equation. By using the Lagrangian with the Rayleigh dissipation function the formulation of equilibrium equations as a unifying technique is examined. At the end electromagnetic forces and torques from the principle of virtual work are studied. Interaction forces from the Euler-Lagrange's equation are also described. The intend of this course module is to learn students how to develop mathematical models of electromechanical systems for problems to which Newton's law, D'Alambert's principle, and Kirchhoff's law can not be conveniently used.

The second module, by Prof. Z. Krzeminski, presents models of electric machines used in designing control systems and in estimation of variables. A scope of lectures is as follows:

1. Preface
2. Basic transformations of frames of references
3. Nonlinear transformations and feedback linearization
4. Multiscalar models of generalized AC machine and linearizing feedback
5. Multiscalar models of the squirrel cage induction machine
6. Saturation effect of main magnetic path of induction machine
7. Feedback linearization of drives with induction machines
8. Models of the permanent magnet synchronous machines
9. Efficient control of AC machines based on simplified models
10. Observer of the induction machines based on extended models

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11. Estimation of speed and position of permanent magnet synchronous machines
12. Estimation of machine parameters
13. Inverters as generators of control signals for the induction motor
14. Control systems based on the multiscalar model of AC machines

Abstract:

Transformation of AC phase variables to orthogonal systems are presented in general form for multiphase machines. Main dependences for transformation of reference frames and general notation are introduced. Vector models of AC machines with variables expressed in different frames of references are determined as basis for further nonlinear transformations.

A class of nonlinear systems defined to model AC machines in a general form. It is shown that nonlinear change of variables and nonlinear feedback applied to the general model of AC machine fully linearizes the system. All variables appearing in the machine model should be available and have to be estimated using models or observers.

Nonlinear transformation of variables and nonlinear feedback applied to known models of AC machines lead to full decoupling of the control system into two linear subsystems. Transformations are specific in dependence on kind of AC machine and results in multiscalar models being generalization of commonly used vector models. Nonlinear feedback requires availability of all variables, including the rotor speed. Precise estimation of variables is achieved in observers based on special extended models of AC machines. A rotor speed is calculated using algebraic formulas of estimated variables. The AC machines may be supplied by voltage or current source inverters and controlled on a basis of different versions of multiscalar models. Results of control are illustrated by simulation and experimental investigations.

Precise nonlinear control of AC machines requires exact parameters of models used in control system. Some special dependencies and properties of machine models or

observers may be exploited to identify machine parameters. Sensitivity to machine parameters in special cases are presented.

Nonlinear control is applied to all types of AC machines which forms general and coherent theory. Comparisons with control systems based on vector models of AC machines are presented and benefits are shown. Possibilities of applications of sophisticated methods of control are pointed out and some examples are presented.

TERMINY WYKLADÓW				
Data	**Dzień tygodnia**	**Godzina**	**Sala**	**Prowadzący**
2014-10-08	Śr	11.15-15.00	EiA E28	dr hab. inż. Andrzej Wilk
2014-10-20	Pn	9.15-12.00	EiA E28	prof. dr hab. inż. Zbigniew Krzemiński
2014-10-21	Wt	9.15-11.00	EiA E28	prof. dr hab. inż. Zbigniew Krzemiński
2014-10-27	Pn	9.15-12.00	EiA E28	prof. dr hab. inż. Zbigniew Krzemiński
2014-10-28	Wt	9.15-12.00	EiA E28	prof. dr hab. inż. Zbigniew Krzemiński

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