Research Team

„Energy Saving Electrical Engineering Equipment“

Department of Electrical Engineering and Mechatronics
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Team Members

prof. Ing. Jaroslav Dudrik, CSc., specialised in research and development of high-frequency indirect soft-switched high-power DC converters (power form ones up to tens of kW).

prof. Ing. Pavol Fedor, PhD., specialised in development of new control structures and applications of modern control methods of electrical drives and multivariable systems.

prof. Ing. Daniela Perduková, PhD., specialised in development of new control structures for complex drive systems and non-linear systems based on artificial intelligence features.

doc. Ing. Jaroslava Žilková, PhD., specialised in modern control methods in field of electrical drives and mechatronic systems utilising artificial intelligence methods (neural networks and fuzzy systems).

doc. Ing. Želmíra Ferková, PhD., specialised in design and modelling of standard and special electrical machines, calculation of electromagnetic and heat fields, utilising of genetic algorithms in electrical drives.

doc. Ing. František Ďurovský, PhD., specialised in modern methods of control of electrical drives and servo-drives (nonlinear control and observers, state-space control, application of genetic algorithms, load torques emulators), control of technological lines, electrical equipment of vehicles.

doc. Ing. Viliam Fedák, CSc., specialised in of single- and multi-motor electrical drives, identification, modelling and simulation of mechatronic systems, design of graphical user interfaces for control of mechatronic systems.

Ing. Marek Pástor, PhD., specialised in control of power semiconductor converters connected into electrical supply network.

Ing. Milan Lacko, PhD., specialised in design and construction of power semiconductor converters and controlling electronics, for power electronics and utilising microcontrollers in variety of applications.

Ing. Karol Kyslan, PhD., specialised in predictive control of electrical drives with finite number of actuating interventions, dynamic emulation of load by Hardware-In-the Loop simulation and Rapid Control Prototyping methods.

Ing. Peter Girovský, PhD., specialised in control of electrical drives utilising neuro- and fuzzy control methods, control of robotic systems and actuators for robotic systems.

Research Direction

Contemporary requirements for technical solutions in field of industrial production are characterised by high-level intensification, minimal consumption and optimisation of technological processes, which cohere with topical questions of electrical energy savings that are priorities of the research across the world.

Consequently, the research is aimed to development of more sophisticated, more energy saving and smaller sized power semiconductor converters for electrical engineering systems in the area of electrical drives, for design of new control methods of electrical drives with high dynamics and taking into consideration energetic optimisation of the control.

The Importance and Benefits of Research

Research of new types of power semiconductor converters is focused on high-frequency soft-switching DC-DC converters for high-power applications (with the switching frequency of tens to hundreds of kHz and output power from ones up to tens of kW). The research goal is minimisation of size and weight of converters, thus reducing the material and manufacturing costs and simultaneously to achieve high efficiency of the converters by using the soft-switching technique. A presumption for achieving the research objectives consists in utilising new, perspective semiconductor devices based on new materials (SiC). Increased switching speed, lower conduction losses and increased temperature resistance of these parts will enable a yet further reduction in size and weight at increased efficiency.

The converters can be utilised for design and construction of the supply sources of constant or controlled DC voltage or current, mainly for laboratory supply sources, chargers, welding sources, sources for illumination engineering, interruptible power supplies, converters for renewable resources and the like.

Research objectives in the area of new control structures for electrical drives and servo-drives with high dynamics are aimed toward increasing of speed and position control precision of servo-drives of low and medium power, taking into account electrical and mechanical non-linearities of the driven machines. Such servo-drives are a part of driving modules of mechatronic components in the area of mechatronics and motion control which are characterised by increased demands for reliability, precision, robustness and energetic power savings. Within the framework of a Joint Associated Laboratory which is focused on development of integrated mechatronics driving modules, the Department of Electrical Engineering and Mechatronics cooperates with company Spinea Prešov (producer of high-precision gears) and ZTS VVÚ Košice (research and development institution).

Solving Current Problems

The research of the power semiconductor converters for electrical engineering systems is carried out in two domains:

- **Converters for DC voltage and current sources for renewable energy resources, welding and automobile technology**.
  The research in this area is oriented towards:
  - High-frequency soft-switching DC- DC converters for high power sources (in the order of ones to tens kW), where predominantly the IGBT transistors are used;
  - Zero current turn off the IGBT transistors in order to eliminate tail current which causes a marked portion in turn off losses;
  - Ability of the converters to maintain soft switching at load changes;
  - Ability of various auxiliary circuits in the converters to recuperate the reactive energy of leakage or parasitic inductance into the load or into the power source.

The basic principles of some from the converters were partially verified by simulation and also by oscilloscope analysis on simplified laboratory models. The results achieved so far suggest that it will be possible to achieve that the power semiconductor switches in these converters operating at almost ideal switching conditions.

- **Converters for BLDC motors**.
  The research in area of the converters for BLDC motors is oriented above all to decreasing of dimensions power part of inverters where the low-voltage MOSFETs are used predominantly. TO minimise the dimensions it is necessary do decrease converter heating, i.e. the total losses where the forward losses create the main portion. The praxis requires to implement the converter into the BLDC motor unit or some applications require creation of one integer: converter plus BLDC motor plus a gear. In case of electrical vehicles it is required to place the BLDC motor into wheel body, ideally together with the converter. In robotic applications there is a tendency to create a unit (servo-motor, joint) converter with the BLDC motor and precise gear.

The theoretical design of each converter is always verified, mathematically described and then verified by computer simulation. Based on the simulation results there is performed an engineering design and product of one or more laboratory models of converters in order to verify experimentally new principles and modes of their operation. Obtained and verified results create a basis for patents and high-quality publication outputs.

Research of new control structures for electrical drives with high dynamics and considering energetic optimisation of control is oriented mainly towards:

- to increasing precision of speed and position control for high dynamic electrical drives of small and middle power:
  - by compensation of mechanical and electrical nonlinearities of the driven equipment
  - and by measurement of variables enabling identification of disturbances (change of the load, change of parameters of the drive);
- to increasing energetic optimisation of the control based on chosen criterion.

The control precision increase can be also obtained by measuring quantities which enable identification of disturbances like change of the load or drive parameters. The identification of disturbances and drive parameters during I motor operation enables adaptation of mathematical model of the drive and adjusting of the control so that the required properties of the control (control precision and energetic optimisation) would be reached.

Properties of new control structures are verified by the numeric simulation and by experimental measurements on specific drives or by using method of HIL simulation on established experimental working place at the department. To verify control structures of drives at their loading the dynamic emulation methods will be applied. They are modern methods of loaded drive control that enable emulate characteristics more-accurately by using a model of mechanic load compared to classical dynamometer.

Current Projects

Grant projects

1. *Research of New Principles and Methods for Design of Electrotechnical Systems.*
   VEGA, 1/0464/15, 2015-2017
   principal investigator: prof. Ing. Jaroslav Dudrik, PhD.
2. *Artificial Methods Application in Control of Industrial Systems.*
   VEGA, 1/0006/10, 2010-2011
   principal investigator: prof. Ing. Jaroslav Timko, PhD.
3. *Research of Power Semiconductor Converters for Industrial and Electric Utility Applications.*
   VEGA, 1/0368/09, 2009-2011
   principal investigator: prof. Ing. Jaroslav Dudrik, PhD.
4. *E-MLAB Ensemble of Original Laboratory Workplaces Supporting and Extending Possibilities of Research-Teaching Laboratories in the Branch of Mechatronics.*
   KEGA, 011TUKE-4/2013, 2013-2015
   principal investigator: prof. Ing. Daniela Perduková, PhD.
5. *Research of Power Semiconductor Converters with High Efficiency for Electric Power Conversion.*
   APVV, APVV-0185-10, 2011-2014
   principal investigator: prof. Ing. Jaroslav Dudrik, PhD.

EU Structural Funds Projects

1. *University Scientific Park TECHNICOM for Innovating Applications with Support of Knowledge Technology.*
   ITMS 26220220182, 2013-2015,
   Principal investigator for the part solved at the Department KEM (Pilot project 2 within framework of the activity 3.2): doc. Ing. František Ďurovský, PhD.
2. *Research of Modules for Intelligent Robotic Systems.*
   ITMS project code: 26220220141. Project recipient: ZTS Research-Development Institute Košice, a.s. (2011-2014). Project partner: TU Košice.
   Principal investigator for the part solved at the Department KEM: doc. Ing. František Ďurovský, PhD.
3. *Centre of Excellence of Power Electronic Systems and Materials for their Components*.
   Project of ESF, No of the agreement 028/2009/2.2/OPVaV, ITMS-NFP26220120003, 1st stage, 05/2009 - 04/2011, ITMS-NFP26220120046, 2nd stage, 9/2010-8/2013 (partner).
   Principal investigator for TU: prof. Ing. Jaroslav Dudrik, PhD.
4. *Development of Low Power Source for Electro Systems*.
   ITMS 26220220029, 2010-2011,
   Principal investigator: prof. Ing. Pavol Fedor, PhD.

Cooperation with Academic Institutions and Industry

Cooperation with Universities

- Technická universita, Liberec, Czech Republic
- Vysoké učení technické, Brno, Czech Republic
- VŠB - Technická universita, Ostrava, Czech Republic
- Technische Universiteit, Delft, The Netherlands
- Sveučiliště u Zagrebu, Croatia
- Universitatea din Oradea, Romania
- Univerza v Mariboru, Slovenia
- Montanuniversität Leoben, Austria
- Budapesti Műszaki és Gazdaságtudományi Egyetem, Hungary

Cooperation with Industry

- Spinea, s.r.o., Prešov
- SEZ Krompachy, a.s.
- Kybernetika, s.r.o., Košice
- U.S.Steel Košice, s.r.o.
- Siemens, s.r.o., Košice
- ZTS VVÚ Košice, a.s.
- Energo Control, s.r.o., Košice
- Associated Laboratory of Integrated Mechatronic Modules for Adaptive Drives (IMMAP). Founders: The Technical University in Košice, Faculty of Electrical Engineering and Informatics, ZTS VVÚ Košice, a.s., Spinea, s.r.o., Prešov

Selected Projects for Praxis

1. Tester Stand for Measurement of Accumulators. Done for ZTS VVÚ, a.s., Košice, 2011.
2. New Circuit Breaker up to 30 A and Appliance for Breaker Hourly Tests, 2008-2010 (in framework of the project APVV 0287-07).
3. Control of Drives for Cross Dividing Production Line. Done for Atenic Commerce, d.o.o. Čačak (Srbsko). Subdelivery for co. Kybernetika, s.r.o., Košice, 2008.
4. Control of Drive for Flying Shear on a Slitting Production Line. co. DZ Hot Rolling Mill Factory (TŠP), U.S.Steel Košice. Subdelivery for co. Kybernetika, s.r.o., Košice, 2007.
5. Drive for a Vertical Descaler on a Roughing Mill. Hot Mill factory, U.S. Steel Košice, s.r.o. Subdelivery for co. Kybernetika, s.r.o., Košice, 2007.
6. Tester 1 of the Thermal Release of Circuit Breakers for SEZ Krompachy, 2006-2007.
7. Tester of the Magnetic Release of Circuit Breakers for SEZ Krompachy, 2004-2005.
8. Modernisation of Converters and Control of the Winder No. 3 in U.S.Steel Košice, s.r.o. Subdelivery for co. Siemens, s.r.o., Košice, 2005.
9. Modernisation of Converters and Control for Conveying Tracks of Winders for co. DZ Hot Strip Mill U.S.Steel Košice. Subdelivery for co. Siemens, s.r.o., Košice, 2005.
10. Tester 2 of the Thermal Release of Circuit Breakers for SEZ Krompachy, 2004-2005.
11. Technical Analyses of Drive Technology and High-Power Electrical Motors.

Selected publications

ADC – Scientific Papers in Current Journals Abroad

1. Dudrik, J., Bodor, M., Pástor, M.: Soft Switching Full – Bridge PWM DC - DC Converter with Controlled Output Rectifier and Secondary Energy Recovery Turn - Off Snubber. IEEE Transactions on Power Electronics. Vol. 29, no. 8 (2014), p. 4116-4125. ISSN 0885-8993
2. Balara, D.; Timko, J.; Žilková, J.: Application of Neural Network Model for Parameters Identification of Non-Linear Dynamic System, NEURAL NETW WORLD, 23 (2): 103-116 (2013)
3. Perduková, D., Fedor, P.: Virtual Laboratory for the Study of Technological Process Automation. International Journal of Engineering Education. TEMPUS Publications 2013. Great Britain, vol. 29, no. 1, pp. 230-238 (2013). ISSN 0949-149X
4. Žilková, J.; Timko, J.; Girovský, P.: Modelling and Control of Tinning Line Entry Section Using Neural Networks. INT J SIMUL MODEL, 11 (2): 97-109 2(2012), DOI: 10.2507/IJSIMM11(2)4.210
5. Dudrik, J., Trip, N. D.: Soft- Switching PS-PWM DC-DC Converter for Full-load Range Applications. IEEE Transactions on Industrial Electronics, IEEE Transactions on Industrial Electronics, vol. 57, no. 8 (2010), pp. 2807-2814. ISSN 0278-0046

ADM – Scientific Papers in Journal Abroad v Registered in Databases Web of Science or Scopus

1. Pástor, M., Dudrik, J.: Predictive Control of Grid-connected Multilevel Inverter with Output LCL Filter. Elektronika ir Elektrotechnika. Vol. 21, no. 3 (2015), p. 10-15. ISSN 1392-1215 (IF=0.561)
2. Fedák, V., Ďurovský, F., Üveges, R., Kyslan, K.: HIL Simulator of Drives of an Industrial Robot with 6 DOF. Elektronika Ir Elektrotechnika. Vol. 21, no. 2 (2015), p. 14-19. ISSN 1392-1215 (IF=0.561)
3. Pástor, M., Dudrik, J.: Comparison of MPC and PI Controller for Grid-connected Cascade Inverter. Elektronika ir Elektrotechnika. Vol. 20, no. 6 (2014), p. 46-50. ISSN 1392-1215 (IF=0.561)

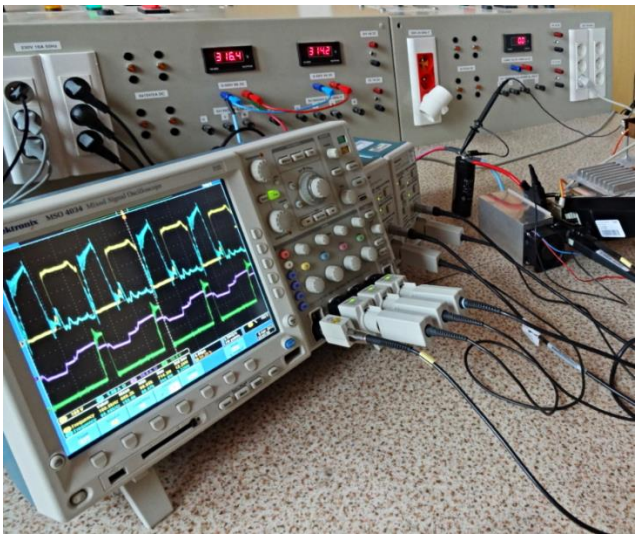
Patents

1. Dudrik, J.: Auxiliary Circuit for Controlled Start Up of the Source. Patent no. 287189, submitted on 29 Mar 2006, no. of application: PP 59-2006, patent granted on 8 Feb 2010.
2. Dudrik, J., Lacko, M.: Non-Dissipative Turn-of Snubber for Converter. Patent no 287292, submitted on 31 Jul 2006, no. of application: PP 112-2006, patent granted on 7 May 2010.
3. Dudrik, J.: Auxiliary Circuits for Achievement of Zero-Current Switching in PWM DC-DC Converters. Patent no. 287742, submitted on 21 Nov 2007, no. of application: PP 0144-2007, granted on 4 Aug 2011
4. Dudrik, J., Ruščin, V., Bodor, M.: Non-Dissipative Turn-Off Snubber for DC-DC Converter with Controlled Output Rectifier. Patent no. 287977, submitted on 16 May 2008, no. of application: PP 112-2006, granted on 12 Jun 2012.
5. Dudrik, J.: Control Method for Soft Switching DC-DC Converter with Secondary Controlled Rectifier. Patent submitted on 2 Dec 2011, no. of application: PP 00136-2011.
6. Dudrik, J., Bodor. M.: Control Method for Soft Switching DC-DC Converter with Secondary Controlled Rectifier. Patent submitted on 14 Feb 2012, no. of application: PP 00012-2012.

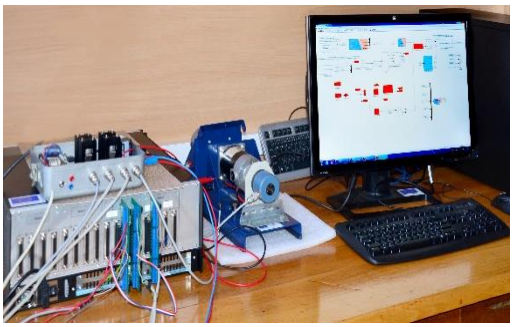
7. Dudrik, J.: Snubber for Reduction of Switching Losses in PWM DC-DC Converters. Patent submitted on 16 Dec 2013, no. of application: PP 00111-2013.
8. Dudrik, J.: Snubber for Decreasing Turn-off Losses and Overvoltages on Secondary Switches in PWM DC-DC Converters. Patent submitted on 19 Jun 2015, no. of application: PP 00046-2015.
9. Dudrik, J., Pástor, M., Lacko, M.: Scheme of a Soft-Switching Switch on Secondary Side of Power Transformer in PWM DC - DC Converters. Patent submitted on 28 Dec 2015, no. of application: PP 00113-2015.

Photos - Research and Development Working Places

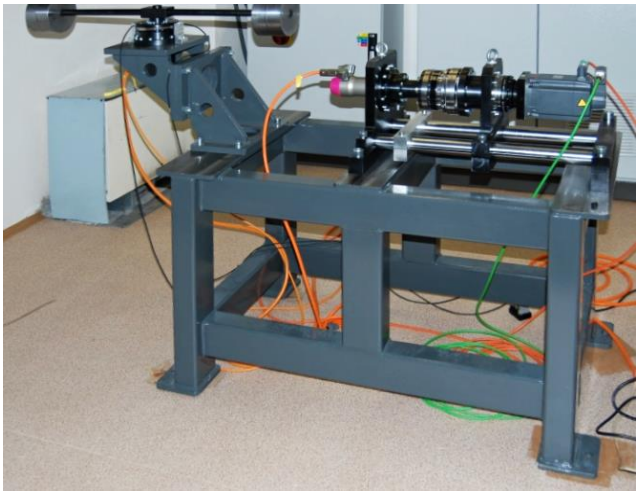
HIL working place based on PLC
for control methods verification of drive system



Working place for research and development of new structures of power semiconductor converters



Research working place for Hardware-in-the-loop simulations and Rapid Control Prototyping



Research working place for loading electrical drives by modern methods of dynamic emulation