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| **UČNI NAČRT PREDMETA / COURSE SYLLABUS** | | | | | | | | | | | | | | | | | |
| **Predmet:** | | | Pretvorniki v močnostni elektroniki | | | | | | | | | | | | | | |
| **Course title:** | | | Power Electronics Converters | | | | | | | | | | | | | | |
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| **Študijski program in stopnja**  **Study programme and level** | | | | | **Študijska smer**  **Study field** | | | | | | | | **Letnik**  **Academic year** | | **Semester**  **Semester** | | |
| **podiplomski doktorski študij tretje stopnje Elektrotehnika** | | | | | **/** | | | | | | | | **1** | | **/** | | |
| **postgraduate doctoral study programme EE - Level III** | | | | | **/** | | | | | | | | **1** | | **/** | | |
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| **Vrsta predmeta / Course type** | | | | | | | | | | | | izbirni/elective | | | | | |
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| **Univerzitetna koda predmeta / University course code:** | | | | | | | | | | | |  | | | | | |
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| **Predavanja**  **Lectures** | **Seminar**  **Seminar** | | | **Vaje**  **Tutorial** | | | **Klinične vaje**  **work** | | | | **Druge oblike študija** | | | **Samost. delo**  **Individ. work** | |  | **ECTS** |
| **30** |  | | |  | | |  | | | |  | | | **95** | |  | **5** |
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| **Nosilec predmeta / Lecturer:** | | | | | Izr. prof. dr. Peter Zajec | | | | | | | | | | | | |
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| **Jeziki /**  **Languages:** | | **Predavanja / Lectures:** | | | | **slovenski / Slovenian** | | | | | | | | | | | |
| **Vaje / Tutorial:** | | | | **/** | | | | | | | | | | | |
| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | | | | | | | | |  | **Prerequisits:** | | | | | | | |
| Formalni pogoj je vpis v 1. letnik študijskega programa 3. stopnje. | | | | | | | | |  | Enrolment in the first year of 3rd cycle (doctoral). | | | | | | | |
| **Vsebina:** | | | | | | | |  | | **Content (Syllabus outline):** | | | | | | | |
| Sodobni študij močnostne elektronike ne obravnava pretvorniških naprav le v luči splošno poznanih kriterijev (izgube, specifična moč pretvornika, ocena njegove življenjske dobe ter stroški izdelave). Vse pomembnejše postaja razumevanje povezovalnih vlog teh pretvorniških naprav v kompleksnih sistemih za učinkovito pretvorbo energije obnovljivih virov v električno energijo in njeno nadaljnjo smotrno pretvorbo ter končno rabo (inteligentno hlajenje in gretje stavb, hibridna vozila, pametna omrežja).  **Detajlnejša vsebina:**  1) Seznanitev s sodobnimi polprevodniškimi močnostnimi stikali ter z izzivi odvajanja izgubne toplote in zmanjšanja parazitnih induktivnosti povezav. Pregled izzivov in študije aktualnih rešitev pri integraciji sestavnih delov pretvornika v enovito celoto (sistemsko in geometrijsko). Mehanizmi odvajanja odvečne toplote, zmanjšanja medsebojnega elektromagnetnega vpliva, doseganje ustrezne prebojne trdnosti in zanesljivosti.  2) Problemi napetostnih in tokovnih strmin v močnostnem delu pretvornikov, razbremenilna vezja, izkoristki in izgube.  3) Pregled osnovnih modulacijskih postopkov (pulznoširinska modulacija, modulacija prostorskega vektorja in ostale) in z njimi povezane specifične rešitve na primeru mejnega obratovanja (obratovanje z majhnim vklopnim razmerjem) obstoječih polprevodniških stikal. Različni principi vodenja polprevodniških pretvornikov. Prediktivni in repetitivni pristopi k vodenju pretvornikov.  4) Povratni vplivi polprevodniških pretvornikov na omrežje in njihovo odpravljanje. Načini razširjanja elektromagnetnih motenj ter ukrepi za njihovo zmanjšanje ali odpravljanje. Merilni sistemi in priprave za diagnostiko prevodnih emisij. Merjenje bližnjih električnih in magnetnih polj.  5) Pregled in analiza sodobnejših trendov pri načrtovanju specifičnih pretvorniških topologij (zaporedna/vzporedna več-celična zasnova pretvornikov, zaporedna/vzporedna vezava močnostnih stikal, združevanje različnih načinov delovanja).  6) Sistemsko orientirana analiza obratovalnih razmer, stabilnostnih pogojev v izbranih, tehnično aktualnih pretvorniških sistemih. Občutljivostne analize v namen zagotavljanja optimalnih obratovalnih lastnosti - s stališča vodenja in pretoka moči (popačenje, izogibanje nezaželenim resonančnim pojavom). | | | | | | | |  | | Nowadays, study of power electronics is not focused only on the generally known criteria list the power converters should comply with: loss reduction, increase of their specific power, estimation of their useful lifetime and the production cost. Increasingly important is to understand their roles in connecting complex systems for the efficient conversion of energy from renewable sources in electricity and its further efficient conversion and end-use in systems such as: smart heating/cooling, hybrid vehicles, smart grids.  **Detailed content:**  1) Insights into modern solid-state power switches and the challenges they face e.g. heat dissipation and reduction of parasitic inductances. Overview of main challenges and study of specific attempts in integration of the converter components into a unified whole (systemically and geometrically). Study of mechanisms of excess heat dispersal, reduction of mutual electromagnetic influence, achieving an appropriate dielectric strength and reliability.  2) Practical design issues, such as snubbers, semiconductor stresses due to the high slope of current and voltage, losses and efficiency.  3) Review of basic modulations (PWM, vector control and others) and related solutions specific to the operation near to the margins (in terms of low duty cycle) of existing semiconductor switches. Various control of semiconductor converters. Predictive and repetitive control methods in power electronics.  4) Effects of power converters to the supply grid voltage and to the adjacent electronic devices. Study of electromagnetic compatibility problems: sources of electromagnetic (EM) emissions, modes of coupling and reduction techniques of EM emissions. Setups for measuring radiated and conducted emissions.  5) Overview and analysis of modern designs in the case of specific converter topologies (serial / parallel multi-cell converter design, serial / parallel connection of power switches, combining different modes of operation).  6) System-oriented analysis of operating conditions, stability conditions in selected state of the art converter systems and sub-systems.  Performing sensitivity analysis to assure various control and power flow aspects (distortion, resonance mitigation). | | | | | | | |

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| **Temeljni literatura in viri / Readings:** | | | | | |
| 1. Bose BK (2010) Power Electronics And Motor Drives: Advances and Trends. Academic Press, London 2. Strzelecki R, Benysek G (2008) Power Electronics in Smart Electrical Energy Networks. Springer, London 3. Orłowska-Kowalska T, Blaabjerg F, Rodríguez J (2014) Advanced and Intelligent Control in Power Electronics and Drives. Springer, New York 4. Fuchs E, Masoum MAS (2011) Power Quality in Power Systems and Electrical Machines. Academic Press, London | | | | | |
| **Cilji in kompetence:** | |  | | **Objectives and competences:** | |
| Cilji: Spodbujati poglobljeno razumevanje o delovanju, tehnoloških in snovnih omejitvah ter vpetosti modernih pretvornikov električne energije v širši znanstveni kontekst. Spodbujati zasledovanje in obvladovanje najsodobnejših postopkov, tehnologij. Okrepiti zavedanje povezovalnih učinkov več-celičnih ter porazdeljenih pretvornikov v primeru njihovega centralnega vodenja.  Kompetence: Nadgradnja temeljnih znanj s področja močnostne elektronike in regulacijske tehnike. Dopolnitev z znanji komplementarnih tehniških vej. | |  | | Objectives: To promote in-depth understanding of the operation, technological and material constraints and the integration of modern inverters power in the wider scientific context. To encourage the cutting-edge design procedures and technologies pursuit. Strengthen awareness of the effects of connecting multi-cell converters and distributed ones in the event of their central control management.  Competencies: Upgrading the basic knowledge in the field of power electronics and control engineering. Gain competences with knowledge of complementary technical branches. | |
| **Predvideni študijski rezultati:** | | |  | **Intended learning outcomes:** | |
| Poglobljeno razumevanje delovanja pretvornikov in njihovih fizikalnih omejitev.  Poznavanje analiznih in načrtovalskih korakov pri reševanju specifičnih problemih pretvorniških vezij. Sposobnost opravljanja in vrednotenja sistemsko orientiranih analiz. | | |  | In-depth understanding of the converters operation and their physical limitations.  To gain knowledge for deeper analysis and design steps in solving specific problems of power electronic converters. The ability to perform system-oriented evaluation and analysis. | |
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| **Metode poučevanja in učenja:** | | |  | **Learning and teaching methods:** | |
| Predavanja ter konzultacije pri izdelavi seminarske naloge in samostojnem študiju po literaturi, vse v navezavi z lastnim raziskovalnim delom. | | |  | Lecture and consultation hours - to assist and lead candidate through his/her homework assignment. | |
| **Načini ocenjevanja:** | Delež (v %) /  Weight (in %) | | | | **Assessment:** |
| Predstavitev seminarja. | 100 | | | | Homework assignment presentation. |
| **Reference nosilca / Lecturer's references:** | | | | | |
| 1. Petkovšek M, Leban A, Nemec M, Vončina D, Zajec P (2013) Series active power filter for high-voltage synchronous generators. Informacije MIDEM, vol. 43, no. 4:228-234  2. Flisar U, Vončina D, Zajec P (2012) Voltage sag independent operation of induction motor based on Z-source inverter. Compel, vol. 31, no. 6:1931-1944  3. Rupar U, Lahajnar F, Zajec P (2012) Iterative-learning-based torque-ripple compensation in a transverse flux motor. IET control theory & applications, vol. 6, no. 3:341-348  4. Petkovšek M, Kosmatin P, Zevnik C, Vončina D, Zajec P (2012) Measurement system for testing of bipolar plates for PEM electrolyzers. Informacije MIDEM, vol. 42, no. 1:60-67  5. Ostrožnik S, Bajec P, Zajec P (2010) A study of a hybrid filter. IEEE transactions on industrial electronics, vol. 57, no. 3:935-942 | | | | | |