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| **UČNI NAČRT PREDMETA / COURSE SYLLABUS** | | | | | | | | | | | | | | | | | |
| **Predmet:** | | | **Regulacijska tehnika** | | | | | | | | | | | | | | |
| **Course title:** | | | **Control Engineering** | | | | | | | | | | | | | | |
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| **Študijski program in stopnja**  **Study programme and level** | | | | | **Študijska smer**  **Study field** | | | | | | | | **Letnik**  **Academic year** | | **Semester**  **Semester** | | |
| **Univerzitetni študijski program prve stopnje Elektrotehnika** | | | | | **Energetika in mehatronika** | | | | | | | | **3.** | | **zimski** | | |
| **1st cycle academic study programme Electrical Engineering** | | | | | **Power Engineering and Mechatronics** | | | | | | | | **3.** | | **winter** | | |
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| **Vrsta predmeta / Course type** | | | | | | | | | | | | obvezni strokovni / compulsory professional | | | | | |
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| **Univerzitetna koda predmeta / University course code:** | | | | | | | | | | | | **64156** | | | | | |
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| **Predavanja**  **Lectures** | **Seminar**  **Seminar** | | | **Vaje**  **Tutorial** | | | **Klinične vaje**  **work** | | | | **Druge oblike študija** | | | **Samost. delo**  **Individ. work** | |  | **ECTS** |
| **60** |  | | | **30** | | |  | | | |  | | | **85** | |  | **7** |
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| **Nosilec predmeta / Lecturer:** | | | | | **David Nedeljković, Vanja Ambrožič** | | | | | | | | | | | | |
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| **Jeziki /**  **Languages:** | | **Predavanja / Lectures:** | | | | **slovenski / slovenian** | | | | | | | | | | | |
| **Vaje / Tutorial:** | | | | **slovenski / slovenian** | | | | | | | | | | | |
| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | | | | | | | | |  | **Prerequisits:** | | | | | | | |
| Vpis v letnik. | | | | | | | | |  | Enrolment in the year of the course. | | | | | | | |
| **Vsebina:** | | | | | | | |  | | **Content (Syllabus outline):** | | | | | | | |
| Linearni sistemi in njihovo opisovanje: diferencialne enačbe, prostor stanj, Laplaceova transformacija in prenosna funkcija, merjenje ali izračun frekvenčnega odziva in podajanje frekvenčne karakteristike v Bodejevem, Nicholsovem in Nyquistovem diagramu, prehodna funkcija. Ponazoritev regulacijskih sistemov z blokovnimi diagrami, prenosne funkcije odprtozančnih in zaprtozančnih sistemov za različne vplivne veličine ter njihova linearizacija in normiranje.  Stabilnost in stabilnostni kriteriji, statični in dinamični pogrešek.  Osnovni gradniki regulacijskih sistemov in njihove lastnosti.  PID regulatorji in njihova realizacija z operacijskimi ojačevalniki.  Optimiranje parametrov regulatorjev: integralski kriteriji, priporočila, potek frekvenčne karakteristike (amplitudna in fazna rezerva), metoda lege korenov.  Kaskadne regulacije, procesne regulacije.  Diskretne regulacije in Z-transformacija, digitalni regulatorji.  Nelinearnosti in njihov vpliv na obnašanje regulacijskih sistemov; analiza stabilnosti nelinearnih sistemov: fazna ravnina, opisna funkcija; odpravljanje integralskega pobega.  Osnove simulacij in uporaba sodobnih programskih orodij za simulacijo regulacijskih sistemov.  Primeri regulacij v močnostni elektrotehniki. | | | | | | | |  | | Linear systems and their descriptions: differential equations, state space, Laplace transform and transfer function, frequency response (Bode, Nyquist, Nichols plots), step response.  Block diagrams, open-loop, closed-loop systems and corresponding transfer functions.  Linearization and normalization.  Stability, steady state error, dynamic error.  Features of elements of control systems in power electronics and electrical drives.  PID controllers, their realization with operational amplifiers and microcontrollers.  Optimization of controllers' parameters.  Cascade control systems, process control systems.  Features of digital control, Z-transform.  Influence of nonlinearities, limit cycles, integrator wind-up.  Basics of simulations and use of appropriate tools in control system design.  Examples of control systems in power electronics and electrical drives. | | | | | | | |

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| **Temeljni literatura in viri / Readings:** | | | | | |
| 1. David Nedeljković: Regulacije v močnostni elektrotehniki, predvideni izid 2016. 2. Gene F. Franklin, J. David Powell, Abbas Emami-Naeini: Feedback control of dynamic systems, Addison-Wesley, 2010. 3. Dogan Ibrahim: Microcontroller based applied digital control: J. Wiley & Sons, 2006. 4. Werner Leonhard: Control of Electrical Drives, Springer; 2001. 5. Vanja Ambrožič, Peter Zajec: Električni servo pogoni, Slovensko združenje elektroenergetikov CIGRÉ-CIRED, 2016. 6. Borut Zupančič, Rihard Karba, Drago Matko: Simulacija dinamičnih sistemov, Univerza v Ljubljani, Fakulteta za elektrotehniko in računalništvo, 1995. 7. Rafael Cajhen: Regulacije, Univerza v Ljubljani, Fakulteta za elektrotehniko in računalništvo, 1990. | | | | | |
| **Cilji in kompetence:** | |  | | **Objectives and competences:** | |
| Študent bo usvojil osnovne pojme s področja regulacijske tehnike, pri čemer bo poudarek pretežno na linearnih sistemih. Spoznal bo različne metode za načrtovanje regulacijskih sistemov in se jih naučil uporabljati s sodobnimi programskimi orodji. Zavedal se bo pomanjkljivosti pri modeliranju in znal bo kritično pristopiti k izvedbi regulacijskih sistemov, zlasti na področju močnostne elektrotehnike. | |  | | The student will master fundamental topics in the field of control engineering, with emphasis on linear systems. He will meet a variety of methods to design control systems and learn how to use these methods with state-of-the-art software tools.  The student will become aware of the modeling inadequacies and will develop a critical approach to design of control systems, especially in the field of power electronics and electrical drives. | |
| **Predvideni študijski rezultati:** | | |  | **Intended learning outcomes:** | |
| **Znanje in razumevanje:**  Študent bo razumel osnovne pojme s področja regulacijske tehnike in spoznal različne načine za opisovanje električnih in mehanskih sistemov.  **Uporaba:**  Študent bo samostojno zasnoval in optimiral preprostejše regulacijske sisteme na področju močnostne elektrotehnike, pri čemer bo po tehtni presoji izbral eno izmed predstavljenih metod.  **Refleksija:**  Študent se bo zavedal prednosti in pomanjkljivosti posameznih pristopov k reševanju regulacijskih problemov ter nevarnosti za neučinkovito regulacijo, ki lahko izvirajo iz njih.  **Prenosljive spretnosti:**  Spretnosti, pridobljene pri tem predmetu, bodo podlaga za poglobljen študij regulacij pri drugih predmetih iz energetike, elektromotorskih pogonov in elektriških tehnoloških procesov. Študent bo tako znanja tega predmeta lahko nadgradil in uporabil za realizacijo zahtevnejših regulacijskih sistemov z najsodobnejšimi tehnološkimi rešitvami. Poleg regulacijskih sistemov v tehniki in naravi bo študent razumel delovanje povratnozančnih sistemov v družbi oziroma njihovo nedelovanje v primeru slabega načrtovanja. | | |  | **Knowledge and understanding:**  The student will understand the basic concepts in the field of control engineering and know different ways to describe the electrical and mechanical systems.  **Application:**  Students will independently design and optimize simpler control systems in the field of power electronics, by taking into consideration one of the presented methods.  **Reflection:**  The student will be familiar with the advantages and shortcomings of different approaches to solving the control engineering problems and he will be aware of the risk of ineffective control that may result from them.  **Transferable skills:**  The skills acquired in this course will provide a basis for in-depth study of control in other courses covering power engineering, electrical drives and electrical technological processes. The student can upgrade the knowledge of this course and use it for the realization of complex control systems with state of the art technological solutions. In addition to control systems in technology and nature, the student will understand the operation of feedback systems in the society, as well as their failure in case of poor planning. | |
| **Metode poučevanja in učenja:** | | |  | **Learning and teaching methods:** | |
| Predavanja (60 ur) in laboratorijske vaje (30 ur); opcija: projektno delo na nalogah, ki potekajo v Laboratoriju za regulacijsko tehniko in močnostno elektroniko. | | |  | Lectures (60 hours) and laboratory work (30 hours); optional: project work on R&D activities within the Laboratory of Control Engineering and Power Electronics. For foreign students: consultations in English and project work. | |
| **Načini ocenjevanja:** | Delež (v %) /  Weight (in %) | | | | **Assessment:** |
| Za pristop k izpitu mora kandidat imeti uspešno opravljene laboratorijske vaje in izdelano poročilo z le-teh.  Pisni in ustni izpit. Kandidat, ki na pisnem izpitu zbere vsaj 50 % možnih točk, lahko pristopi k ustnemu izpitu. Končna ocena se oblikuje na podlagi rezultata pisnega izpita in ustnega zagovora, pri katerem se upošteva tudi poročilo z laboratorijskih vaj.  Kandidat lahko opravi pisni izpit tudi z dvema kolokvijema, pri čemer mora na vsakem kolokviju doseči vsaj 50 % možnih točk.  Kandidatom, ki se vključijo v projektno delo in nalogo uspešno zaključijo, ni treba opravljati pisnega in ustnega izpita, temveč se jim ocena poda na podlagi njihovega angažiranja na projektu in pri tem usvojenih znanj.  Ocenjevalna lestvica:  nezadostno (od 1 do 5), zadostno (6), dobro (7), prav dobro (8), prav dobro (9), odlično (10). | Pisni izpit 50%, ustni izpit 50%  /  Written exam 50%, oral exam 50% | | | | Before taking the exam the student has to accomplish the laboratory work and to prepare the corresponding report.  Written and oral exam. The candidate who passes the written exam with at least 50% of all possible points can take the oral examination. Final assessment is formed on the basis of the result of written and oral examination, where the student's report on laboratory work is also taken into account.  The candidate can pass the written exam by taking 2 colloquia and exceeding score 50% on each of them.  The grade for the candidates involved in the project work that successfully accomplish their task can be formed on the basis of student's knowledge acquired during his/her engagement within the project.  Grading scale: poor (1 to 5), adequate (6), good (7), very good (8), very good (9), excellent (10). |
| **Reference nosilca / Lecturer's references:** | | | | | |
| **David Nedeljković:**  1. KONTARČEK, Andraž, BAJEC, Primož, NEMEC, Mitja, AMBROŽIČ, Vanja, NEDELJKOVIĆ, David. Cost-effective three-phase PMSM drive tolerant to open-phase fault. IEEE transactions on industrial electronics, ISSN 0278-0046. [Print ed.], Nov. 2015, vol. 62, no. 11, str. 6708-6718.  2. SLADIĆ, Saša, SKOK, Srđan, NEDELJKOVIĆ, David. Efficiency considerations and application limits of single-phase active power filter with converters for photoenergy applications. International journal of photoenergy, 2011, vol. 2011, str. 1-8.  3. DROBNIČ, Klemen, NEMEC, Mitja, NEDELJKOVIĆ, David, AMBROŽIČ, Vanja. Predictive direct control applied to AC drives and active power filter. IEEE trans. ind. electron. (1982. Print). [Print ed.], Jun. 2009, vol. 56, no. 6, str. 1884-1893.  4. AMBROŽIČ, Vanja, FIŠER, Rastko, NEDELJKOVIĆ, David. Direct current control - a new current regulation principle. IEEE trans. power electron., jan. 2003, vol. 18, no. 1, str. 495-503.  5. NEDELJKOVIĆ, David, NASTRAN, Janez, VONČINA, Danijel, AMBROŽIČ, Vanja. Synchronization of active power filter current reference to the network. IEEE trans. ind. electron. (1982. Print). [Print ed.], 1999, vol. 46, no. 2, str. 333-339.  **Vanja Ambrožič:**  1. NEMEC, Mitja, DROBNIČ, Klemen, NEDELJKOVIĆ, David, FIŠER, Rastko, AMBROŽIČ, Vanja. Detection of broken bars in induction motor through the analysis of supply voltage modulation. IEEE trans. ind. electron. (1982. Print). [Print ed.], Aug. 2010, vol. 57, no. 8, str. 2879-2888.  2. NEMEC, Mitja, DROBNIČ, Klemen, NEDELJKOVIĆ, David, AMBROŽIČ, Vanja. Direct current control of a synchronous machine in field coordinates. IEEE trans. ind. electron. (1982. Print). [Print ed.], Oct. 2009, vol. 56, no. 10, str. 4052-4061.  3. NEMEC, Mitja, NEDELJKOVIĆ, David, AMBROŽIČ, Vanja. Predictive torque control of induction machines using immediate flux control. IEEE trans. ind. electron. (1982. Print). [Print ed.], Aug. 2007, vol. 54, no. 4, str. 2009-2017.  4. AMBROŽIČ, Vanja, BUJA, Giuseppe S., MENIS, Roberto. Band-constrained technique for direct torque control of induction motor. IEEE trans. ind. electron. (1982. Print). [Print ed.], 2004, vol. 51, no. 4, str. 776-784.  5. AMBROŽIČ, Vanja, ZAJEC, Peter. Električni servo pogoni. 1. izd. V Ljubljani: Slovensko združenje elektroenergetikov CIGRÉ-CIRED, 2016. | | | | | |