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| **UČNI NAČRT PREDMETA / COURSE SYLLABUS** | | | | | | | | | | | | | | | | | |
| **Predmet:** | | | Dinamični pojavi v elektroenergetskih sistemih | | | | | | | | | | | | | | |
| **Course title:** | | | Power System Dynamic Phenomena | | | | | | | | | | | | | | |
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| **Študijski program in stopnja**  **Study programme and level** | | | | | **Študijska smer**  **Study field** | | | | | | | | **Letnik**  **Academic year** | | **Semester**  **Semester** | | |
| Podiplomski magistrski študijski program druge stopnje Elektrotehnika | | | | | Elektroenergetika | | | | | | | | 2 | | 1 | | |
| 2nd cycle masters study programme in Electrical Engineering | | | | | Electrical Power Engineering | | | | | | | | 2 | | 1 | | |
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| **Vrsta predmeta / Course type** | | | | | | | | | | | | Obvezni-strokovni t/ Compulsory professional | | | | | |
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| **Univerzitetna koda predmeta / University course code:** | | | | | | | | | | | | 64283 | | | | | |
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| **Predavanja**  **Lectures** | **Seminar**  **Seminar** | | | **Vaje**  **Tutorial** | | | **Klinične vaje**  **work** | | | | **Druge oblike študija** | | | **Samost. delo**  **Individ. work** | |  | **ECTS** |
| 45 |  | | | 30 | | |  | | | |  | | | 75 | |  | 6 |
|  | | | | | | | | | | | | | | | | | |
| **Nosilec predmeta / Lecturer:** | | | | | Rafael Mihalič | | | | | | | | | | | | |
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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 predmeta | | | | | | | | |  | Enrolment in the year of the course | | | | | | | |
| **Vsebina:** | | | | | | | |  | | **Content (Syllabus outline):** | | | | | | | |
| Osnovni pojmi in vzroki nastanka dinamičnih pojavov v elektroenergetskih sistemih (EES), osnovni tipi prehodnih pojavov in temeljni principi analize posameznih vrst prehodnih pojavov, principi modeliranja elementov EES za analizo dinamičnih pojavov glede na časovni okvir dinamike pojava, analiza pojavov, ki jih obravnavamo s principi linearizacije sistemov (prostor stanj, lastne vrednosti, vodljivost, spoznavnost, ), metode reševanja časovno diskretnih sistemov, analiza pojavov, ki jih obravnavamo z metodami analize nelinearnih sistemov, analiza značilnih dinamičnih pojavov v EES (samovzbujena nihanja, tranzientna stabilnost, frekvenčna nestabilnost, potujoči valovi, asinhronski tek generatorjev, prehodni pojavi v generatorju, kratek stik v sistemu, udarni momenti generatorjev ob motnjah v omrežju, izklop kapacitivnosti, subsinhrona resonanca), ukrepi za stabilizacijo EES, osnove digitalne simulacije dinamičnih pojavov v EES, nadomestne sheme elementov EES, značilnosti numerične nestabilnost in ukrepi za odpravo, določitev začetnih pogojev omrežja, določitev začetnih pogojev za sklop generator – turbinska regulacija – napetostna regulacija, osnovne značilnosti programskih orodij za obravnavo dinamičnih pojavov, simulacije v trenutnem načinu, simulacije v stabilnostnem načinu, simulacije v realnem času. | | | | | | | |  | | Basic facts and ground reasons behind electric power system (EPS) dynamic phenomena occurrence, categorization of different dynamic phenomena, basic principles for analysis of each phenomenon type, EPS elements modelling principles for different time-scale dynamic phenomena, small-signal stability EPS analysis (linear state-space modelling, eigenvalues, system controllability and observability, etc.), methods for discrete-time systems analysis, approaches to non-linear systems dynamic phenomena analysis, analysis of typical and most common types of EPS dynamic phenomena (oscillations, transient stability, frequency stability, travelling waves, asynchronous operation of a synchronous machine, transient phenomena within a synchronous machine, short-circuit events in EPS, impact torque on synchronous generators as a consequence of different EPS events, capacitive-current switching, sub-synchronous resonance), measures for the stabilization of EPS operation, basic principles of dynamic phenomena digital simulation techniques, equivalent circuits of different EPS elements, numerical instability issues and measures for its avoidance, setting-up EPS model initial conditions, setting-up initial conditions for a composite model synchronous generator – governor – exciter, basic characteristics of dynamic simulation software tools, momentary mode dynamic simulations, stability mode dynamic simulations, real-time dynamic simulations. | | | | | | | |

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| **Temeljni literatura in viri / Readings:** | | | | | |
| 1. MIHALIČ, Rafael*. Stabilnost in dinamični pojavi v elektroenergetskih sistemih : osnovni pojmi s primeri*. Ljubljana: Slovensko združenje elektroenergetikov CIGRÉ - CIRED, 2013. 261 str., ilustr. ISBN 978-961-6265-23-2. 2. Kundur P., Power System Stability and Control, McGraw Hill, 1994. 3. Machowski J. Bialek J. W., Bumby J. R., Power System Dynamics and Stability, John Wiley & Sons, 1997. | | | | | |
| **Cilji in kompetence:** | |  | | **Objectives and competences:** | |
| Pregled dinamičnih pojavov v EES in njihova razdelitev glede na osnovne karakteristike, usmeritve in pristopi k analizi in reševanju vzrokov posameznih dinamičnih pojavov v EES, uporaba matematičnih znanj iz področja diferencialnega računa za analizo dinamičnih pojavov v EES, razumevansje ozadja delovanja programske opreme za analizo dinamičnih pojavov v EES. | |  | | EPS dynamic phenomena overview and categorization with regards to their characteristics, guidance and approaches to analysis and solving each EPS dynamic phenomena, application of mathematical differential equation solving knowledge for analysis of EPS dynamic phenomena, understanding the background of EPS dynamic simulation software operation. | |
| **Predvideni študijski rezultati:** | | |  | **Intended learning outcomes:** | |
| Študent se seznani z vzroki, vplivnimi veličinami in posledicami dinamičnih pojavov v EES in njihovim vplivom na obratovanje EES. Spozna tipične vrste dinamičnih pojavov in uveljavljene načine pristopa k obravnavi teh pojavov. V okviru slednjega se seznani z načini ponazoritve komponent EES in metodami za analizo pojavov. Spozna metode in osnovna načela delovanja programov za simulacijo dinamike EES ter značilne probleme in napake, ki se pojavljajo ob simulaciji dinamičnih pojavov v EES. | | |  | Student becomes familiar with reasons behind different EPS dynamic phenomena as well as corresponding influential variables and potential consequences of each of them. Most common types of EPS dynamic phenomena are introduced and explained. Also, appropriate analysing approaches for each are described. With regards to this, students obtains knowledge about specifics of EPS elements modelling for observing different dynamic phenomena. Methods and basic principles for dynamic EPS simulations are explained, along with most common issues that might appear in the process. | |
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| **Metode poučevanja in učenja:** | | |  | **Learning and teaching methods:** | |
| Predavanja in laboratorijske vaje | | |  | Lectures and practical laboratory courses | |
| **Načini ocenjevanja:** | Delež (v %) /  Weight (in %) | | | | **Assessment:** |
| Način: laboratorijske vaje, pisni izpit, ustni izpit.  Ocene od 1 do vključno 5 so negativne, ocene od vključno 6 do 10 so pozitivne.  Pozitivna ocena laboratorijskih vaj je pogoj za pristop k izpitu.  Prispevki k oceni:  laboratorijske vaje  pisni izpit  ustni izpit | 50%  25%  25% | | | | Type: laboratory exercises, written exam, oral exam.  Negative grades: from 1 to 5, positive grades: from 6 to 10.  Positive evaluation of laboratory exercises is a prerequisite for the exam.  Contributions to final grade:  laboratory exercises  written exam  oral examination |
| **Reference nosilca / Lecturer's references:** | | | | | |
| 1. MIHALIČ, Rafael*. Stabilnost in dinamični pojavi v elektroenergetskih sistemih : osnovni pojmi s primeri*. Ljubljana: Slovensko združenje elektroenergetikov CIGRÉ - CIRED, 2013. 2. RUDEŽ, Urban, MIHALIČ, Rafael. Analysis of underfrequency load shedding using a frequency gradient. *IEEE transactions on power delivery*, vol. 26, no. 2, str. 565-575. 3. MIHALIČ, Rafael, GABRIJEL, Uroš. A structure-preserving energy function for a static series synchronous compensator. *IEEE transactions on power systems*, vol. 19, no. 3, str. 1501-1507. 4. RUDEŽ, Urban, MIHALIČ, Rafael. Monitoring the first frequency derivative to improve adaptive underfrequency load-shedding schemes. *IEEE transactions on power systems*, 2011, vol. 26, no. 2, str. 839-846. 5. GAŠPERIČ, Samo, MIHALIČ, Rafael. The impact of serial controllable FACTS devices on voltage stability. *International journal of electrical power & energy systems*, Jan. 2015, vol. 64, str. 1040-1048. | | | | | |