TRAJNOSTNI VIRI ELEKTRIČNE ENERGIJE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Trajnostni viri električne energije
Course title:	Sustainable sources of electric energy
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	**Študijska smer**	**Letnik**	**Semestri**	**Izbirnost**
Strojništvo - Razvojno raziskovalni program, druga stopnja, magistrski	Energetsko strojništvo (smer)	2. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0566865
Koda učne enote na članici/UL Member course code:	6010-M

Predavanja /Lectures	**Seminar /Seminar**	**Vaje /Tutorials**	**Klinične vaje /Clinical tutorials**	**Druge oblike študija /Other forms of study**	**Samostojno delo /Individual student work**	**ECTS**
30		30			65	5

Nosilec predmeta/Lecturer:	Marko Hočevar, Martin Petkovšek

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course	Obvezni strokovni predmet na smeri Energetsko

type:	strojništvo, ki je izbirni strokovni predmet na ostalih smereh./Compulsory specialised course in the study of Energy engineering, which is an elective specialised course in other fields of study.

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Izpolnjevanje pogojev za vpis v Magistrski študijski program II. stopnje Strojništvo - Razvojno raziskovalni program.	Meeting the enrollment conditions for the Master's study programme of Mechanical Engineering - Research and Development program.

Vsebina:	**Content (Syllabus outline):**
1. Uvod: Predavanja potek dela, obveznosti študentov, pomen vodnih in vetrnih turbin ter sončnih celic v elektroenergetskem sistemu danes in v prihodnosti 2. Vodne turbine 1: Predavanja opis gradnikov pretočnega trakta turbine in pomen za delovanje (Peltonove, Francisove, Kaplanove in cevne turbine), lastnosti, oblika in delovanje drugih tipov vodnih turbin: Saxo, Banki, Deriaz, Gorlov, Turgo, vodno kolo, hidrokinetični tipi turbin, vodne turbine za izrabo energije valov, ribam prijazne vodne turbine Alden, delovanje ribam prijaznih vodnih turbin 3. Vodne turbine 2: Predavanja Eulerjeva enačba, trikotniki hitrosti, karakteristika, izkoristek in školjčni diagrami za neregulirane, regulirane in dvojno regulirane vodne turbine, pojavljanje kavitacijskega vrtinca in drugih vrst kavitacije v gonilniku in v školjčnem diagramu, povezava lastnosti kavitacijskega vrtinca s trikotniki hitrosti, kavitacijska erozija 4. Izdelava vodnih turbin: Predavanja za Peltonove, Francisove, Kaplanove in cevne turbine, postopki izdelave lopatic, pesta in obroča za velike, srednje in	1. Introduction: Lectures workflow, student responsibilities, the importance of water and wind turbines and solar cells in the electricity system today and in the future 2. Water turbines 1: Lectures description of the components of the turbine flow tract and importance for operation (Pelton, Francis, Kaplan and tube turbines), properties, design and operation of other types of water turbines: Saxo, Banks, Deriaz, Gorlov, Turgo, water wheel, hydrokinetic types of turbines, water turbines for use of wave energy, Alden fish-friendly water turbines, operation of fish-friendly water turbines 3. Water turbines 2: Lectures Euler equation, velocity triangles, characteristic, efficiency and hill diagrams for non-regulated, regulated and double regulated water turbines, the occurrence of cavitation vortex and other types of cavitation in the runner and hill diagram, relation of cavitation vortex properties with velocity triangles, cavitation erosion 4. Manufacture of water turbines: Lectures for Pelton, Francis, Kaplan and tubular

male premere, metode preverjanja kvalitete izdelave, predmontaža in montaža vodnih turbin, balansiranje	turbines, blades, hub, and ring manufacturing processes for large, medium and small diameters, quality control methods, prefabrication and installation of water turbines, balancing
5. Načrtovanje vodnih turbin 1: Predavanja	5. Design of water turbines 1: Lectures
izkoristek, bruto in neto padec, brezdimenzijska števila: tlačno, pretočno, močnostno število in hitrostno število, hitrosti toka po pretočnem traktu, premer in vrtilna frekcenca, vpliv števila polov generatorja, vpliv kavitacije	efficiency, gross and net head, dimensionless numbers: pressure, flow rate, power numbers and speed number, flow velocities along the streamline, diameter and speed, the influence of generator pole number, cavitation influence
6. Načrtovanje vodnih turbin 2: Predavanja	6. Design of water turbines 2: Lectures
vpliv kavitacije in NPSH, primer načrtovanja spiralnega ohišja, gonilnika in sesalne cevi Francisove turbine, uporaba računalniške dinamike tekočin	influence of cavitation and NPSH, the example of spiral casing design, runner and suction tube of Francis turbine, use of computational fluid dynamics
7. Gradniki vodne elektrarne: Predavanja	7. Elements of a water power plant: Lectures
jez, rešetka, zapornica, odpeskovalna zapornica, zobje, vodostan, rov, kanal, tlačni rov, tlačni regulator, predturbinski ventil, bypass, iztočni in vtočno iztočni objekt, itd., pomožni gradniki vodne turbine: ležaji, tesnilka, detektor pomikov, zavore, turbinski regulator, hidravlični agregat, agregat, generator, gred, protidvižna plošča, vztrajnik, mazalni sistemi, hlajenje, itd., gradniki prelivnih polj: jezovi, zapornice, zagatnice, zobje, ribje steze, itd.	dam, trash racks, dam, sand trap, teeth, surge tank, tunnel, duct, penstock, pressure regulator, pre-turbine valve, bypass, outlet, and outlet facility, etc., auxiliary components of water turbine: bearings, seal, creep detector, brakes, turbine regulator, hydraulic power unit, aggregate, generator, shaft, anti-lift plate, flywheel, lubrication systems, cooling, etc., spillway building blocks: dams, barriers, locks, teeth, fish lanes, etc.
8. Vetrne turbine: Predavanja	8. Wind turbines: Lectures
vetrne turbine z vodoravno in navpično gredjo: Darieusova, Savoniusova turbina itd., reduktor, generator, ohranitev masnega toka in energije, Betzov kriterij, koeficient moči, koeficienti potiska, napredovanja, upora in vzgona	horizontal and vertical wind turbines: Darrieus, Savonius turbine, etc., gearbox, generator, conservation of mass flow and energy, Betz criterion, power factor, thrust coefficients, advancement, drag and lift
9. Načrtovanje oblike lopatic vetrnih turbin: Predavanja	9. Wind turbine blade design: Lectures
izkoristek, največja moč vetrne turbine, materiali za lopatice vetrnih turbin, regulacija moči, stall	efficiency, maximum wind turbine power, materials for wind turbine blades, power control, stall
10. Umeščanje vetrnih elektrarn v prostor: Predavanja	10. Installation of wind farms in the environment: Lectures
orientacija postavitve, polja vetrnih elektrarn, delovanje v mrežo povezanih in avtonomnih vetrnih elektrarn in fotovoltaičnih modulov	layout orientation, wind farm fields, networking of connected and autonomous wind farms and photovoltaic modules
11. Lastnosti sončnih celic: Predavanja	11. Properties of solar cells: Lectures
	principle of operation, semiconductors,

princip delovanja, polprevodniki, materiali, tehnologije: monokristalne, polikristalne in amorfne sončne celice, izkoristek sončnih celic, 12. Razvoj sončnih celic: Predavanja smernice razvoja sončnih celic, drugi tipi sončnih elektrarn, koncentrirane sončne elektrarne, shranjevanje energije. 13. Shranjevanje električne energije: Predavanja shranjevanje energije s prečrpovalnimi elektrarnami, baterijami, power to gas, izračun potreb po shranjevanju v prihodnosti, itd. 14. Pomen hitrega odziva elektrarne za zagotavljanje sistemskih storitev omrežja 1: Predavanja pomen frekvenčnih pretvornikov za delovanje vodnih, vodnih prečrpovalnih in vetrnih turbin v elektroenergetskem sistemu, pomen za hitri zagon in primarno regulacijo 15. Pomen hitrega odziva elektrarne za zagotavljanje sistemskih storitev omrežja 2: Predavanja črpalne hidroelektrarne, delovanje v štirih kvadrantih, stabilnost elektroenergetskega sistema, vključevanje baterij v sistem črpalnih elektrarn	materials, technologies: single-crystalline, polycrystalline and amorphous solar cells, solar cell efficiency, 12. Solar cell development: Lectures solar cell development guidelines, other types of solar power plants, concentrated solar power plants, energy storage. 13. Electricity storage: Lectures energy storage with pumped-storage power plants, batteries, the power to gas, calculation of future storage needs, etc. 14. Importance of a power plant's rapid response to the provision of network system services 1: Lectures importance of frequency converters for the operation of water, water pumping and wind turbines in the power system, the importance for quick start-up and primary control 15. Importance of a rapid response from a power plant to provide system services for network system services 2: Lectures pumping hydropower plants, four-quadrant operation, the stability of the power system, integration of batteries into the pumping power system

Temeljna literatura in viri/Readings:

1. Marko Hočevar, Introduction to turbine machinery, Fakulteta za strojništvo, učbenik, 2019
2. Marko Hočevar, Uvod v hidroenergetske sisteme, Fakulteta za strojništvo, učbenik, 2015
3. Ahmed F. Zobaa, Handbook of renewable energy technology, World scientific publishing company, 2011

Cilji in kompetence:	**Objectives and competences:**
Cilji: 1. Spoznati princip delovanja vodnih in vetrnih elektrarn ter sončnih celic 2. Spoznati osnovne gradnike vodnih in vetrnih elektrarn 3. Razumeti energijske pretvorbe v strojih in napravah za izrabo trajnostnih virov energije	Objectives: 1. To learn the principle of operation of hydro and wind power plants and solar cells 2. To learn the basic building blocks of hydropower and wind power plants 3. Understand energy conversions in machines and devices for the use of

4. Razumeti interakcijo strojev in naprav za izrabo trajnostnih virov energije z omrežjem 5. Spoznati načine in pomen shranjevanja energije Kompetence: 1. Sposobnost načrtovanja sistemov za preskrbo z elektriko iz trajnostnih virov (S1-MAG) 2. Sposobnost razmevanja interakcije sistemov za preskrbo z elektriko iz trajnostnih virov in električnega omrežja (P2-MAG) 3. Sposobnost diagnosticiranja posebnosti in napak delovanja sistemov za preskrbo z elektriko iz trajnostnih virov (P7-MAG) 4. Sposobnost sprejemanja odločitev glede delovanja naprav in sistemov proizvodnje elektrike iz trajnostnih virov (S8-MAG) 5. Zmožnost kritičnega razmišljanja in ocenjevanja vplivov na okolje naprav in sistemov proizvodnje elektrike iz trajnostnih virov (S9-MAG)	sustainable energy sources 4. Understand the interaction of machines and devices for utilizing sustainable energy sources with the grid 5. Know the ways and importance of energy storage Competencies: 1. Sustainable power supply systems design capability (S1-MAG) 2. The ability to contemplate the interaction of systems for the supply of electricity from sustainable sources and the electricity grid (P2-MAG) 3. Ability to diagnose the specifics and failures of sustainable power systems (P7-MAG) 4. Ability to make decisions regarding the operation of sustainable electricity generation devices and systems (S8-MAG) 5. Ability to think critically and evaluate the environmental impact of sustainable power generation plants and systems (S9-MAG)

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: 1. Z2: Poglobljeno teoretično, metodološko in analitično znanje z elementi raziskovanja, ki je osnova za zelo zahtevno znanstveno in strokovno delo na področju sinteze, načrtovanja, uporabe in napovedovanja delovanja sistemov za preskrbo z elektriko iz trajnostnih virov. Spretnosti: 1. S2.1: Izvajanje kompleksnih metod za izračunavanje karakteristik delovanja sistemov za preskrbo z elektriko iz trajnostnih virov v okolje. 2. S2.2: Upravljanje sistemov za preskrbo z elektriko iz trajnostnih virov v okolje.	Knowledge: 1. Z2: In-depth theoretical, methodological and analytical knowledge with elements of research, which is the basis for very demanding scientific and professional work in the field of synthesis, design, use, and forecasting of the operation of systems for the supply of electricity from sustainable sources. Skills: 1. S2.1: Implementation of complex methods for calculating the performance characteristics of sustainable electricity supply systems in the environment. 2. S2.2: Management of electricity supply systems from sustainable sources to the environment.

Metode poučevanja in učenja:	Learning and teaching methods:
Klasične oblike poučevanja: P1: Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov. P2: Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri in razlago, potrebno za razumevanje laboratorijskih vaj. P3: Laboratorijske vaje z namenskimi didaktičnimi pripomočki kot so gradniki merilne postaje, različni turbinski stroji in fotocelice, dušilniki, frekvenčni pretvorniki merilniki pretoka, temperature, relativne vlažnosti, tlaka, električne moči itd. *Moderne in prožne oblike poučevanja:* P4: Uporaba študijskega slikovnega in filmskega gradiva za predstavitev delovanja in uporabe naprav in sistemov proizvodnje elektrike iz trajnostnih virov. P5: Uporaba študijskega gradiva kot so modeli računalniške dinamike tekočin s predstavitvijo geometrijske oblike naprav in sistemov proizvodnje elektrike iz trajnostnih virov, tlačnega in hitrostnega polja ter tokovnic z odprtokodno programsko opremo za analizo podatkov in vizualizacijo (npr. Paraview). P6: Študij literature in razprava. P7: Skupinsko delo, razprava, strukturirana diskusija med laboratorijskimi vajami in ekskurzijami. P8: Virtualni eksperimenti za določanje lastnosti naprav in sistemov proizvodnje elektrike iz trajnostnih virov.	*Classical forms of teaching:* P1: Lectures including solving selected - typical and practical examples. P2: Tutorials where theoretical knowledge of the lectures is supported by computational examples and explanations needed to understand the lab work. P3: Laboratory exercises with dedicated didactic aids such as measuring station building blocks, various turbine machines and photocells, flaps, frequency converters flow meters, temperatures, relative humidity, pressure, electrical power meters, etc. *Modern and flexible forms of teaching:* P4: Use of studio image and movie materials to demonstrate the operation and use of sustainable power generation devices and systems. P5: Use of study materials such as models of computational fluid dynamics by presenting the geometric design of devices and systems for generating electricity from sustainable sources, pressure and velocity fields, and open source software for data analysis and visualization (eg Paraview). P6: Literature studies and discussion. P7: Group work, discussion, the structured discussion between lab work and field trips. P8: Virtual experiments to determine the properties of devices and systems for generating electricity from sustainable sources.

Načini ocenjevanja:	Delež/ Weight	Assessment:
sodelovanje pri laboratorijskih vajah	15,00 %	participation in lab work

poročila o laboratorijskih vajah	10,00 %	lab report
kolokvij pri laboratorijskih vajah	25,00 %	laboratory exams
izpit	50,00 %	exam

Reference nosilca/Lecturer's references:

Marko Hočevar:

1. HOČEVAR, Marko, NOVAK, Lovrenc, RAK, Gašper. Future needs for energy storage in the alpine region = Prihodnje potrebe po shranjevanju energije v alpskem prostoru. Acta hydrotechnica. 2019, letn. 32, št. 56, str. 35-43. [COBISS.SI-ID 8908897]
2. Podnar Andrej, Dular Matevž, Širok Brane, Hočevar Marko. Experimental analysis of cavitation phenomena on kaplan turbine blades using flow visualization. Journal of fluids engineering : Transactions of the ASME. Jul. 2019, vol. 141, iss. 7, str. 1-13. [COBISS.SI-ID 16442651]
3. RAK, Gašper, HOČEVAR, Marko, STEINMAN, Franci. Measuring water surface topography using laser scanning. Flow measurement and instrumentation. [Print ed.]. avg. 2017, letn. 56, str. 35-44. [COBISS.SI-ID 8119905]
4. Cencič Tine, Hočevar Marko, Širok Brane. Study of erosive cavitation detection in pump mode of pump-storage hydropower plant prototype. Journal of fluids engineering : Transactions of the ASME. May 2014, vol. 136, no. 5, str. 051301-1-051301-11. [COBISS.SI-ID 13375771]
5. POTOČAR, Erik, ŠIROK, Brane, HOČEVAR, Marko, EBERLINC, Matjaž. Control of separation flow over a wind turbine blade with plasma actuators. Strojniški vestnik. jan. 2012, vol. 58, no. 1, str. 37-45. [COBISS.SI-ID 12192795]

Martin Petkovšek:

1. PETKOVŠEK, Martin, MLAKAR, Matej, LEVSTEK, Meta, STRAŽAR, Marjetka, ŠIROK, Brane, DULAR, Matevž. *A novel rotation generator of hydrodynamic cavitation for waste-activated sludge disintegration*. Ultrasonics Sonochemistry. Sep. 2015, vol. 26, str. 408-414, ilustr. ISSN 1350-4177. DOI: 10.1016/j.ultsonch.2015.01.006. [COBISS.SI-ID 13878811]
2. ŠARC, Andrej, STEPIŠNIK PERDIH, Tadej, PETKOVŠEK, Martin, DULAR, Matevž. *The issue of cavitation number value in studies of water treatment by hydrodynamic cavitation*. Ultrasonics Sonochemistry. Jan. 2017, vol. 34, str. 51-59, ilustr. ISSN 1350-4177. http://www.sciencedirect.com/science/article/pii/S1350417716301626, DOI: 10.1016/j.ultsonch.2016.05.020. [COBISS.SI-ID 14676763]
3. KOLBL REPINC, Sabina, BIZJAN, Benjamin, BUDHIRAJA, Vaibhav, DULAR, Matevž, GOSTIŠA, Jurij, BRAJER HUMAR, Barbara, KAURIN, Anela, KRŽAN, Andrej, LEVSTEK, Meta, MORALES ARTEAGA, Juan Francisco, PETKOVŠEK, Martin, RAK, Gašper, STRES, Blaž, ŠIROK, Brane, ŽAGAR, Ema, ZUPANC, Mojca. *Integral analysis of hydrodynamic cavitation effects on waste activated sludge characteristics, potentially toxic metals, microorganisms and identification of microplastics.* Science of the total environment. Feb. 2022, vol. 806, pt. 4, str. 1-14, ilustr. ISSN 0048-9697. https://www.sciencedirect.com/science/article/pii/S0048969721064925, DOI: 10.1016/j.scitotenv.2021.151414. [COBISS.SI-ID 83741955]
4. NOVAK, Lovrenc, PETKOVŠEK, Martin, OMAN, Simon, NAGODE, Marko, KLEMENC, Jernej, MAJDIČ, Franc, HOČEVAR, Marko, GOSAR, Aleš, OLAH,

Laslo. *Downhole three phase separator and method for use of same : United States Patent US 11,143,009 B1, 2021-10-12*. Alexandria (VA): United States Patent and Trademark Office, 2021. [12] f., ilustr. https://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PTXT&s1=Oman.INNM.&OS=IN/Oman&RS=IN/Oman, https://worldwide.espacenet.com/patent/search/family/078007966/publication/US11143009B1?q=pn%3DUS11143009B1. [COBISS.SI-ID 73371651] patentna družina: US202117341815A, 2021-06-08; US202063036990P, 2020-06-09

5. ŠIROK, Brane, DULAR, Matevž, PETKOVŠEK, Martin. *Cavitation device for treatment of water by cavitation : United States patent US10202288 B2, 2019-02-12*. [S.l.]: Unated States Patent and Trademark Office, 2019. 9 f., ilustr. [COBISS.SI-ID 14615835] patentna družina: US2016167983 (A1), 2016-06-16; DE102013013813, 2013-08-22; DE102013013813 (A1), 2015-02-26; CN105683091 (B), 2018-01-16; EP3036201 (B1), 2017-05-03; WO2015024654 (A1), 2015-02-26
6. BIZJAN, Benjamin, HOČEVAR, Marko, DULAR, Matevž, NOVAK, Lovrenc, **PETKOVŠEK, Martin**. *Turbinski stroji : vaje : gradivo za vaje pri predmetu Turbinski stroji : študijsko gradivo*. Ljubljana: Fakulteta za strojništvo, 2016. 1 optični disk (CD-ROM), ilustr. [COBISS.SI-ID 15056155]