HIDRO IN VETRNI ENERGETSKI SISTEMI

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Hidro in vetrni energetski sistemi
Course title:	HYDRO AND WIND ENERGY SYSTEMS
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni (od študijskega leta 2023/2024 dalje)	Energetsko strojništvo (smer)	3. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0562725
Koda učne enote na članici/UL Member course code:	3026-V

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			40	4

Nosilec predmeta/Lecturer:	Benjamin Bizjan, Marko Hočevar

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

Izvajalci praktičnega usposabljanja:	
Vrsta predmeta/Course type:	Izbirni strokovni predmet /Elective specialised course

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

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Izpolnjevanje pogojev za vpis v Visokošolski strokovni študijski program I. stopnje Strojništvo - Projektno aplikativni program.	Meeting the enrollment conditions for the MECHANICAL ENGINEERING - Project Oriented Applied Programme.

Vsebina:	**Content (Syllabus outline):**
1. Uvod: potek dela, obveznosti študentov zgodovina in razdelitev vodnih in vetrnih turbin. 2. Opis tipov vodnih turbin: Peltonova, Francisova, Kaplanova in cevna turbina, delovanje, glavni sestavni deli, opis gradnikov pretočnega trakta turbine in pomen za delovanje. 3. Izdelava vodnih turbin: za Peltonove, Francisove, Kaplanove in cevne turbine, postopki izdelave lopatic, pesta in obroča za velike, srednje in male premere, metode preverjanja kvalitete izdelave, predmontaža in montaža vodnih turbin, balansiranje. 4. Gradniki hidroenergetskega sistema I: jez, rešetka, zapornica, odpeskovalna zapornica, zobje, vodostan, rov, kanal, tlačni rov, tlačni regulator, predturbinski ventil, bypass, iztočni in vtočno iztočni objekt, itd. 5. Gradniki hidroenergetskega sistema II: 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,	1. Introduction: workflow, student obligations history and classification of water and wind turbines. 2. Description of types of water turbines: Pelton, Francis, Kaplan and bulb turbines, operation, main components, description of the components of the turbine flow tract and importance for operation. 3. Manufacture of water turbines: for Pelton, Francis, Kaplan and tubular turbines, procedures for manufacturing blades, hubs and rings for large, medium and small diameters, methods of quality control, pre-assembly and installation of water turbines, balancing. 4. The building blocks of hydropower system I: dam, trash rack, gate, sand trap, teeth, surge chamber, tunnel, channel, penstock, pressure regulator, pre-turbine valve, bypass, outlet and outlet facility, etc. 5. Hydropower system building blocks II: auxiliary building blocks of a water turbine: bearings, seal, displacement detector, brakes, turbine regulator, hydraulic power unit, generator, shaft, flywheel, lubrication systems, cooling, etc., spillway elements: dams, gates,

ribje steze, itd. 6. Podobnost v vodnih turbinah: pretočno, tlačno in močnostno število, specifična hitrost. 7. Energijske pretvorbe v vodnih turbinah: 1. in 2. Eulerjeva enačba turbinskih strojev, padci in izkoristek. 8. Trikotniki hitrosti v vodnih turbinah: tok vode v radialnih in aksialnih vodnih turbinah v točki najboljšega izkoristka in izven nje. 9. Kavitacija v vodnih turbinah: pojavljanje vrtinca in drugih vrst kavitacije v gonilniku in v školjčnem diagramu, NPSH. 10. Načrtovanje vodnih turbin: postopek izbire glede na pretok, padec, specifično hitrost in NPSH. 11. Uvod v vetrne turbine: vetrne turbine z vodoravno in navpično gredjo: Darieusova, Savoniusova turbina itd., reduktor, generator, ohranitev masnega toka in energije. 12. Betzov kriterij: določitev največje moči vetrne turbine, aerodinamika toka vetrne turbine, koeficient moči, koeficienti potiska, napredovanja, upora in vzgona. 13. Načrtovanje lopatic vetrnih turbin: izkoristek, upor, vzgon, največja moč vetrne turbine, materiali za lopatice vetrnih turbin, regulacija moči, stall. 14. Izdelava vetrnih turbin: postopki izdelave lopatic, pesta, reduktorja, generatorja, balansiranje, montaža. 15. Umeščanje vodnih in vetrnih turbin v prostor: pretoki in padci vodotokov, izbira tipa vodne turbine, polja vetrnih turbin in orientacija, delovanje v mrežo povezanih in avtonomnih vetrnih turbin in fotovoltaičnih modulov.	locks, teeth, fish lanes, etc. 6. The similarity in water turbines: flow, pressure, and power numbers, specific speed. 7. Energy conversion in water turbines: 1st and 2nd Eulerian equation of turbine machines, head, and efficiency. 8. Velocity triangles in water turbines: Water flow in radial and axial water turbines, at and away from the point of maximum efficiency. 9. Cavitation in water turbines: Occurrence of the vortex and other types of cavitation in runner and hill diagram, NPSH. 10. Design of water turbines: Selection process according to flow, drop, specific speed and NPSH. 11. Introduction to wind turbines: wind turbines with horizontal and vertical shafts: Darrieus, Savonius turbines, etc., gearbox, generator, conservation of mass flow and energy. 12. Betz criterion: determination of maximum wind turbine power, the aerodynamics of wind turbine flow, power coefficient, thrust and coefficients, drag and lift. 13. Design of wind turbine blades: efficiency, drag, lift, maximum wind turbine power, materials for wind turbine blades, power regulation, stall. 14. Manufacture of wind turbines: procedures for the manufacture of blades, hubs, gearboxes, generators, balancing, assembly. 15. Placement of water and wind turbines in the environment: flows and falls of watercourses, choice of the type of water turbine, wind turbine fields, and orientation, operation in a network of connected and autonomous wind turbines and photovoltaic modules.

Temeljna literatura in viri/Readings:

1. Marko Hočevar in Matevž Dular, Uvod v hidroenergetske sisteme, Fakulteta za strojništvo, učbenik, 2015
2. Marko Hočevar, Introduction to turbine machinery, Fakulteta za strojništvo,

učbenik, 2019
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 hidro in vetrnih energetskih sistemov 2. Spoznati osnovne gradnike hidro in vetrnih energetskih sistemov 3. Razumeti energijske pretvorbe v hidro in vetrnih energetskih sistemih 4. Razumeti spreminjanje delovnih spremenljivk po posameznih elementih hidro in vetrnih energetskih sistemov 5. Spoznati način izdelave in obratovanja hidro in vetrnih energetskih sistemov Kompetence: 1. S7-PAP: Sposobnost sprejemanja odločitev v hidro in vetrnega energetskega sistema, ki se nanašajo na način obratovanja. 2. P1-PAP: Sposobnost razmevanja interakcije hidro in vetrnega energetskega sistema z okolico. 3. P3-PAP: Sposobnost razumevanja delovanja gradnikov hidro in vetrnega energetskega Sistema. 4. P8-PAP: Sposobnost diagnosticiranja posebnosti in napak delovanja hidro in vetrnega energetskega sistema.	Objectives: 1. To learn the principle of operation of hydro and wind energy systems 2. Learn the basic building blocks of hydro and wind energy systems 3. Understand energy conversions in hydro and wind energy systems 4. Understand the variation of operating variables by individual elements of hydro and wind energy systems 5. To learn how to build and operate hydro and wind energy systems Competencies: 1. S7-PAP: Ability to make decisions in hydro and wind energy systems that relate to operating mode. 2. P1-PAP: Ability to consider the interaction of hydro and wind energy systems with the environment. 3. P3-PAP: Ability to understand the operation of the building blocks of a hydro and wind energy system. 4. P8-PAP: Ability to diagnose the peculiarities and problems of operation of a hydro and wind power system.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: Z1: Poglobljeno strokovno teoretično in praktično znanje na področju hidro in vetrnih energetskih sistemov, podprto s širšo teoretično in metodološko osnovo. Spretnosti: S1.1: Izvajanje kompleksnih operativno-strokovnih opravil, ki vključujejo tudi uporabo metodoloških orodij na področju hidro in vetrnih energetskih sistemov.	Knowledge: Z1: In-depth professional theoretical and practical knowledge in the field of hydro and wind energy systems, supported by a broader theoretical and methodological basis. Skills: S1.1: Performing complex operational and professional tasks that also include the use of methodological tools in the field of hydro and wind energy systems.

S1.2: Uporaba modernih metod za izbiro in analizo delovanja hidro in vetrnih energetskih sistemov.	S1.2: Application of modern methods for selecting and analyzing the operation of hydro and wind energy systems.

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 drugi gradniki hidro in vetrnih energetskih sistemov, 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 hidro in vetrnih energetskih sistemov P5: Uporaba študijskega gradiva kot so modeli računalniške dinamike tekočin s predstavitvijo geometrijske oblike hidro in vetrnih energetskih sistemov, 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 hidro in vetrnih energetskih sistemov.	Classical forms of teaching: P1: Lectures including solving selected - typical and practical examples. P2: Tutorials where theoretical knowledge of the lectures is supported by analytical and computational examples and explanations needed to understand the lab work. P3: Laboratory exercises with dedicated didactic aids such as measuring station building blocks, various other building blocks of hydro and wind energy systems, flaps, frequency converters flow meters, temperatures, relative humidity, pressure, electrical power meters, etc. Modern and flexible forms of teaching: P4: Use of study image and movie materials to demonstrate the operation and use of hydro and wind energy systems P5: Use of study materials such as computational fluid dynamics models, presenting the geometric shape of hydro and wind energy systems, 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 hydro and wind power systems.

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*. [Spletna izd.]. 2019, letn. 32, št. 56, str. 35-43, ilustr. ISSN 1581-0267. ftp://ksh.fgg.uni-lj.si/acta/a32mh.pdf, DOI: 10.15292/acta.hydro.2019.03. [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, ilustr. ISSN 0098-220 http://fluidsengineering.asmedigitalcollection.asme.org/article.aspx?articleID=2715661, DOI: 10.1115/1.4041985. [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, ilustr. ISSN 0955-5986. DOI: 10.1016/j.flowmeasinst.2017.07.004. [COBISS.SI-ID 8119905]
4. CENCIČ, Tine, **HOČEVAR, Marko**, ŠIROK, Brane. Study of erosive cavitation detection in pump mode of pumpstorage hydropower plant prototype. *Journal of fluids engineering : Transactions of the ASME*. May 2014, vol. 136, no. 5, str. 051301-1-051301-11, ilustr. ISSN 0098-2202. DOI: 10.1115/1.4026476. [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, si 8, ilustr. ISSN 0039-2480. http://en.sv-jme.eu/data/upload/2012/01/07_2011_016_Potocar_03.pdf, DOI: 10.5545/sv-jme.2011.016. [COBISS.SIID 12192795]

Benjamin Bizjan:

1. **BIZJAN, Benjamin**, MILAVEC, Matej, ŠIROK, Brane, TRENC, Ferdinand, HOČEVAR, Marko. Energy dissipation in the blade tip region of an axial fan. Journal of sound and vibration. [Print ed.]. Nov. 2016, vol. 382, str. 63-72, ilustr. ISSN 0022-460X. http://ac.els-cdn.com/S0022460X16302772/1-s2.0-S0022460X16302772- main.pdf?_tid=5fdbb8b2-7b4f-11e7-9dde-00000aacb362&acdnat=1502096830_9b99d023102c0d763ba4fbc6fadb21a8, DOI: 10.1016/j.jsv.2016.06.036. [COBISS.SI-ID 14747163]
2. BLAGOJEVIĆ, Bogdan, ŠIROK, Brane, **BIZJAN, Benjamin**. Novel methodology for turbine gas meters error curve modelling across a wide range of operating parameters = Neuartige Methodik für Fehlerkurvenmodellierung bei Turbinenradgaszählern über einen weiten Bereich von Betriebsparameter. TM : Technisches Messen. 2021, vol. 88, iss. 11, str. 702-713, ilustr. ISSN 0171-8096.

https://www.degruyter.com/document/doi/10.1515/teme-2021- 0083/html, DOI: 10.1515/teme-2021-0083. [COBISS.SI-ID 71066115]

3. **BIZJAN, Benjamin**, ŠIROK, Brane, BLAGOJEVIČ, Marko. Experimental investigation of liquid disintegration by twin spinning wheel atomizer. Chemical engineering research & design. Jan. 2021, vol. 165, str. 230-241, ilustr. ISSN 0263-8762. https://www.sciencedirect.com/science/article/abs/pii/S0263876220300587?via%3Dihub, DOI: 10.1016/j.cherd.2020.02.002. [COBISS.SI-ID 14089731]
4. ŠIROK, Brane, PLATIŠA, Anton, DOLENC, Sašo, **BIZJAN, Benjamin**, PETERNELJ, Marko. Method and device for producing mineral wool fibers : international publication number WO 2016/048249 A1, 2016-03-31. [Geneva]: World Intellectual Property Organization, 2016. 22 f., 3 f. pril., ilustr. https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2016048249. [COBISS.SI-ID 13805595]
5. **BIZJAN, Benjamin**, ŠIROK, Brane, GOSTIŠA, Jurij, DULAR, Matevž, ZUPANC, Mojca. Liquid decontamination system comprising a cavitation device and method of decontamination of a liquid : WO2022112191A1, 2022-06-02. Geneva: World Intellectual Property Organization, 2022. [31] str., ilustr. https://worldwide.espacenet.com/patent/search/family/074215999/publication/WO2022112191A1?q=pn%3DWO20 22112191A1. [COBISS.SI-ID 50299907]
6. NOVAK, Lovrenc, HOČEVAR, Marko, PETKOVŠEK, Martin, **BIZJAN, Benjamin**, ZUPANC, Mojca. Zbirka laboratorijskih vaj za predmet Trajnostni viri električne energije : MAG, 2. letnik. Ljubljana: Fakulteta za strojništvo, 2022. 1 USB ključ (1 datoteka PDF (33 str.)), ilustr. [COBISS.SI-ID 136028419]
7. **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]