UNIVERSITY OF SPLIT

FACULTY OF ELECTRICAL ENGINEERING, MECHANICAL ENGINEERING AND NAVAL ARCHITECTURE

DETAILED PROPOSAL OF THE STUDY PROGRAMME

GRADUATE UNIVERSITY STUDY IN ELECTRICAL ENGINEERING

SPLIT, February 2022

List ofmandatory and elective courses

List ofcourses									
Year of study:1.									
Semester: I.									
STATUS	CODE	COURSE	HOURS IN SEMESTER						ECTS
			L	S	AE	LE	DE		
Mandatory	FENI36	Basics of Energy Engineering	30	0	0	15	0		4
	L = lectures, S = seminars, AE = auditoryexcercise, LE = laboratoryexcercise, DE = design excercise								

Specialisation: Automation and drives - 231

List ofcourses								
Year of study:1.								
Semester: II								
STATUS	CODE	COURSE	HOURS IN SEMESTER					ECTS
			L	S	AE	LE	DE	
	FENI12	Modeling of Electromechanical Systems	30	0	0	30	0	6
	FENI13	Embedded Computer Systems	30	0	0	30	0	6
	FENI14	Semiconductor Power Converters	30	0	0	30	0	6
	FENI19	Measurements of Process Quantities	30	0	0	30	0	6
	Total		150	0	0	150	0	30
	L = lectures, S = seminars, AE = auditoryexcercise, LE = laboratoryexcercise, DE = design excercise							

List ofcourses								
Year of study:2.								
Semester: III.								
STATUS	CODE	COURSE	HOURS IN SEMESTER					ECTS
			L	S	AE	LE	DE	
Mandatory	FENI16	Automated electrical drives	30	0	0	15	0	4
Mandatory	FENI41	Energy storage systems	30	0	0	15	0	4
	L = lectures, S = seminars, AE = auditoryexcercise, LE = laboratoryexcercise, DE = design excercise							

Specialisation: Power systems - 232

List ofcourses								
Year of study:1.								
Semester: II								
STATUS	CODE	COURSE	HOURS IN SEMESTER					ECTS
			L	S	AE	LE	DE	
	FENI08	Power Plants	45	0	0	15	0	6
	L = lectures, S = seminars, AE = auditoryexcercise, LE = laboratoryexcercise, DE = design excercise							

List ofcourses								
Year of study:2.								
Semester: III.								
STATUS	CODE	COURSE	HOURS IN SEMESTER					ECTS
			L	S	AE	LE	DE	
	FENI10	Protection at Substations	45	0	0	15	0	7
Elective	FENI23	Lightning protection and earthing	30	0	0	15	0	4
	FENI46	Smart Grids	30	0	0	15	0	4
	L = lectures, S = seminars, AE = auditoryexcercise, LE = laboratoryexcercise, DE = design excercise							

1.1. Course description

NAME OF THE COURSE	**BASICS OF ENERGY ENGINEERING**							
Code	FENI36	Year of study	1.					
Course teacher	RankoGoić, Ph.D., Full Professor	Credits (ECTS)	4					
Associate teachers	Josip Vasilj, Ph.D.; Stipe Vodopija, M.Sc.	Type of instruction (number of hours)	L	S	AE	LE	DE	
			30	0	0	15	0	
Status of the course	Obligatory	Percentage of application of e-learning	0					

COURSE DESCRIPTION	
Course objectives	Training students for: - understanding of basic concepts and characteristics of energy sources and energy conversion processes, - understanding of energy conversions in power plants - understanding of concepts of sustainable energy development and energy efficiency - understanding of interdependence of energy, environment and economy - preparation of spreadsheet models for calculation of electricity costs
Course enrolment requirements and entry competences required for the course	None
Learning outcomes expected at the level of the course (4 to 10 learning outcomes)	Students will be able to: - describe basic characteristics of conventional and renewable energy, - apply of key concepts of sustainable energy use and energy efficiency, - prepare simple models for calculation of energy-economic parameters of power plants - prepare simple models for tariff system analysis and optimization of use of electrical energy,

Course content broken down in detail by weekly class schedule (syllabus)		
	Course content	L hours
	Sources and types of energy. Primary, transformed and useful forms of energy.	3
	Reserves, types and basic characteristics of non-renewable and renewable energy sources.	3
	Transformations of non-renewable energy sources in power plants.	3
	Transformations of renewable energy sources in power plants.	3
	Energy and environment. Global warming and influence on energy.	3
	Energy balances and flows. Prices and availability of energy.	3
	Energy efficiency and rational use of energy. Cogeneration.	3
	Principles of tariff systems in energy. Energy planning.	3
	Networked energy systems and its characteristics: electrical energy, gas, centralized heating systems.	3
	Energy laws. Energy markets.	3
	List of laboratory exercises	LE hours
	MS Excel model for calculation of energy-economic parameters of PV power plant.	3
	MS Excel model for calculation of energy-economic parameters of wind power plant.	3

	MS Excel model for calculation of energy-economic parameters of hydro power plant.	3
	MS Excel model for calculation of household electricity cost.	3
	Site visit to PV power plant or wind power plant.	3

Format of instruction	☒ lectures ☒ seminars and workshops ☒ exercises ☐*on line* in entirety ☐ partial e-learning ☐ field work	☐ independent assignments ☒ multimedia ☒ laboratory ☐ work with mentor ☐ (other)
Studentresponsibilities	The presence on lectures in the amount of at least 70 % of the times scheduled. Performed all required laboratory exercises.	

Screening student work *(name the proportion of ECTS credits for eachactivity so that the total number of ECTS credits is equal to the ECTS value of the course)*	Class attendance	1,4	Research		Practical training	
	Experimental work		Report		Individual work	0,7
	Essay		Seminar essay	1	Laboratory exercises	0,4
	Tests	0,2	Oral exam		Preparation for laboratory exercises	0,2
	Written exam	0,1	Project		(Other)	

Grading and evaluating student work in class and at the final exam	There are two midterms and final exams. The first midterm exam, covering all lectures, is being held after 14 weeks of lecturing in form of written test. The second midterm exam is carried out in form of seminar essay on selected topic after 12 weeks of lecturing. In the two final exams students that did not pass the first midterm exams must repeat the test. Students who did not pass the entire exam after two final exams can pass the exam in the two additional exams. The requirement for passing grade of the course is at least 50 % of written test in midterm, final or additional exam and positively graded seminar essay. Grade (in percentage) is formed according to following formula: Grade (%) = 0,5xKP+0,25xS1+0,15xS2+0,1xP, Activities in percentage: • KP- written test results • S1 – grade of seminar essay • S2 – grade of seminar essay presentation • P – attendance at lectures Grade (in number) is formed as follows: • 50 % to 61 % - pass (2) • 62 % to 74 % - good (3) • 75 % to 87 % - very good (4) • 88 % to 100 % - excellent (5)

Required literature (available in the library and via other media)	**Title**	**Number of copies in the library**	**Availability via other media**
	Goić, R., "PredavanjaizOpćeenergetike ", Sveučilište u Splitu, FESB, Split, 2013. (internal script)		e-learning portal
	Duić, N., EnerPEDIA - http://www.powerlab.fsb.hr/enerpedia	1	www

Optional literature (at the time of submission of study	• B. Udovičić: Osnoveenergetike, Školskaknjiga, Zagreb, 1991. • H. Požar: Osnoveenergetike I, II i III, Školskaknjiga, Zagreb, 1992.

programme proposal)	
Quality assurance methods that ensure the acquisition of exit competences	• Evaluation of results in accordance with the above learning outcomes • Feedback from students via surveys • Self-evaluation of teachers • Institutional and non-institutional evaluations
Other (as the proposer wishes to add)	

NAME OF THE COURSE	**MODELING OF ELECTROMECHANICAL SYSTEMS**						
Code	FENI12	Year of study	1.				
Course teacher	Marin Despalatović, Ph.D., Associate Professor	Credits (ECTS)	6				
Associate teachers		Type of instruction (number of hours)	L	S	AE	LE	DE
			30			30	
Status of the course	Obligatory	Percentage of application of e-learning	0				
COURSE DESCRIPTION							
Course objectives	Training students for: 1. Modeling of electromechanical systems, especially different types of electrical machines and drives, 2. Analysis of electric drives characteristics using tools for computer modeling and simulation (Matlab, Simulink, SymPowerSystems, PLECS).						
Course enrolment requirements and entry competences required for the course	Competences and skills acquired with the bachelor degree in Electrical Engineering.						
Learning outcomes expected at the level of the course (4 to 10 learning outcomes)	Students will be able to: 1. Comment electromechanical energy conversion, 2. Compare different types of electrical machines using general two axis machine model, 3. Propose variables transformation matrix and object model suitable for the system synthesis, 4. Model different types of electromechanical systems, 5. Estimate the model parameters based on measurements of electrical and/or mechanical quantities, 6. Analyze the computer obtained responses of electric machinery variables by comparing them with corresponding measurements obtained in the laboratory, 7. Predict the characteristics of electrical drive based on the theoretical knowledge and use of tools for computer modeling and simulation.						

Course content broken down in detail by weekly class schedule (syllabus)	Course content	L or S hours
	Basic analysis of electromechanical systems: linear equations of magnetically coupled circuits, basic concepts and definitions, simulation of magnetically coupled circuits with saturated core.	2
	Electromechanical energy conversion - accumulated magnetic energy, electromagnetic force and torque.	2
	The general model of electrical machine: structure, assumptions and omissions, the equations of the electrical machine in a general form, the balance of power in the electric machine.	2
	The voltage equation in the original coordinates, flux linkages, inductance matrix, resulting space vectors of two-phase variables.	2
	The equation of the electromagnetic torque in the original coordinates, the conditions for a permanent electromechanical energy conversion.	2
	Transformation of coordinates: the transformation between two rotating reference frames of different speeds, matrix and vector form of transformation, resulting space vectors of three-phase variables.	2
	General transformation matrix of three-phase variables, the transformation of symmetric three-phase circuit with resistances, inductive and capacitive elements, the transformation of symmetric three-phase sinusoidal system.	2
	First midterm exam	2
	Two axis theory of electric machines: general model with transformed variables, transformation to the stationary reference frame, voltage equations and the torque equation in the stator coordinate system, the reduction of parameters and equivalent circuit schematic for direct and quadrature axis.	2
	Electric machine with salient poles on the rotor: determination of inductance based on a comparison with the general model, transformation to the rotor reference frame, voltage equations and the torque equation in the rotor coordinate system, a comparison with the general model of electric machine.	2
	Electric machine with a constant air gap: voltage equations and torque equation in an arbitrarily rotating reference frame, the equivalent circuit diagram. The per unit system: base values, the application of the per unit values on the two axis models of electric machines.	2
	DC machine: reduction of general model equations to DC machine configuration. DC machine as a linear dynamic system. Startup and sudden load of separately excited DC machine: analytical solutions, simulation of chopper (thyristor converter) fed DC machine.	2
	Induction machine: reduction of the three-phase induction motor to two-axis model, steady state voltage equations, initial conditions, linearized model of induction machine, a model of a lower order, simulation of frequency converter fed induction machine.	2
	Synchronous machine: reduction of synchronous machine without damper winding to two-axis model, modeling of synchronous machine with damping winding, modeling of synchronous machine with permanent magnets on the rotor, steady state voltage equations, the power angle, electromagnetic torque, initial conditions, simulation of inverter fed synchronous machine.	2
	Second midterm exam	2
	List of laboratory or design exercises	LE or DE hours
	1. Simulation of transients in the transformer.	4
	2. Simulation of saturation - switching transformer to the grid.	2

	3. Simulation of transients in the elementary electromechanical device.	4
	4. Transformations of variables between three-phase and two-phase rotating reference frames.	4
	5. Simulation of transients in the DC machine.	4
	6. Simulation of transients in the induction machine.	4
	7. Simulation of transients in the synchronous machine.	4
	8. Simulation of transients in the AC machine with permanent magnets.	4

Format of instruction	☒ lectures ☐ seminars and workshops ☒ exercises ☐*on line* in entirety ☐ partial e-learning ☐ field work	☐ independent assignments ☒ multimedia ☒ laboratory ☐ work with mentor ☐ (other)
Studentresponsibilities	The presence on lectures in the amount of at least 70% of the times scheduled. Performed all laboratory exercises.	

Screening student work *(name the proportion of ECTS credits for eachactivity so that the total number of ECTS credits is equal to the ECTS value of the course)*	Class attendance	1,0	Research		Practical training	
	Experimental work		Report		Individual work	3,3
	Essay		Seminar essay		Laboratory exercises	1,0
	Tests	0,1	Oral exam		Preparation for laboratory exercises	0,5
	Written exam	0,1	Project		(Other)	

Grading and evaluating student work in class and at the final exam	There are two midterm exams during semester. The first midterm exam is after 7 weeks of lecturing and the second one is after the next 6 weeks. By midterm exams students can pass the entire exam. On the exam (final, correctional and commission) students take the parts of material which they did not pass on the midterm or previous exams. A separate part of the material means the material of each midterm exam. The exams are carried out as written tests. The duration of the midterm exams are 60 minutes, while exams are 2x60 minutes. The requirement for passing grade is at least 50% of points on each (midterm) exam and the positive assessment (minimum 50% of points) of all laboratory exercises. Grade (in percentage) is formed as follows: Grade(%) = (ME1 + ME2 + LE) / 3 where ME1, ME2 - points obtained at (midterm) exams expressed in percentages LE - average grade of all laboratory exercises expressed in percentages The final grade is determined as follows: Percentage Grade 0% to 49% insufficient (1) 50% to 61% sufficient (2) 62% to 74% good (3) 75% to 87% very good (4) 88% to 100% excellent (5) Exam group: 22 Examinations are held in accordance with the course calendar schedule.

	Title	**Number of copies in the library**	**Availability via other media**
Required literature (available in the library and via other media)	M. Jadrić, B. Frančić: Dinamikaelektričnihstrojeva, Graphis, Zagreb, 2004.	3	
	The Simulation Platform for Power Electronic Systems, PLECS User Manual (Ver 4.0), Plexim GmbH, Zurich, 2016.		e-learning portal
	SimPowerSystems User's Guide, The MathWorks, Inc., Natick, 2010.		e-learning portal
Optional literature (at the time of submission of study programme proposal)	P. C. Krause, O. Wasynczuk, S. D. Sudhoff, S. Pekarek: Analysis of Electric Machinery and Drive Systems (3rd Edition), Wiley-IEEE Press, New York, 2013. C.-M. Ong: Dynamic Simulation of Electric Machinery (Using Matlab/Simulink), Prentice Hall, Upper Saddle River, 1998.		
Quality assurance methods that ensure the acquisition of exit competences	- Keeping records of students course attendance - Annual review of the performance of the examinations - Evaluation of results in accordance with the above learning outcomes - Feedback from students via surveys - Self-evaluation of teachers - Institutional and non-institutional evaluations		
Other (as the proposer wishes to add)			

NAME OF THE COURSE	**EMBEDDED COMPUTER SYSTEMS**		
Code	FENI13	Year of study	1
Course teacher	Ozren Bego, Ph.D., Associate Professor	Credits (ECTS)	6

			L	S	AE	LE	DE
Associate teachers	Danijel Jolevski, Ph.D., Assistant Professor	Type of instruction (number of hours)	30	0	0	30	0

Status of the course	Obligatory	Percentage of application of e-learning	0

COURSE DESCRIPTION

Course objectives	Training students for: - understanding idea of embedded computer systems, - understanding concept of microprocessors and its periphery, - programing microprocessors in assembler, - design of simpler embedded computer devices.
Course enrolment requirements and entry competences required for the course	None.
Learning outcomes expected at the level of the course (4 to 10 learning outcomes)	Students will be able to: - define and choose microprocessor in embedded system, - design microprocessor based device, - program microprocessor, - analyze quality and functionality of embedded computer system.

Course content broken down in detail by weekly class schedule (syllabus)

Course content	L or S hours	AE hours
Introduction in course. Introduction in microprocessors.	2	
Standard microprocessor architecture. Functions of ALU, instruction decoder, accumulators/registers,	2	
Model of Atmel ATmega16 microcontroller.	2	
Addressing modes. Review of modes in ATmega16,	2	
Microprocessor instructions. Review of ATmega16 instructions.	2	
Microprocessor busses. Memory types	2	
Concept of transfer data between I/O and CPU; programming I/O. Review of ATmega16 periphery.	2	
Interrupted access to periphery. Application on ATmega16.	2	
Periphery: A/D and D/A convertors.	2	
Periphery: parallel data transfer.	2	
Periphery: serial data transfer. Synchronous and asynchronous serial transfer.	2	
Standards and protocols for serial data transfer.	2	
Higher languages for microprocessor programing.	2	

List of laboratory or design exercises	LE or DE hours
Introduction in ATmega16 microcontroller and IDE AVR Studio.	3
Introduction in Easy AVR 5A platform for development embedded system with Atmel microcontrollers.	3
Programing ATmega16 – instructions.	6
Peripheral of ATmega16 – interrupts.	2

	Peripheral of ATmega16 – timer/counter, PWM.	2
	Peripheral of ATmega16 – ADC, comparator, LCD.	2
	Seminar: Design of embedded computer system; independent/group assignments.	12

Format of instruction	☒ lectures ☒ seminars and workshops ☒ exercises ☐*on line* in entirety ☐ partial e-learning ☐ field work	☒ independent assignments ☐ multimedia ☒ laboratory ☐ work with mentor ☐ (other)
Studentresponsibilities		

Screening student work *(name the proportion of ECTS credits for eachactivity so that the total number of ECTS credits is equal to the ECTS value of the course)*						
	Class attendance	1	Research		Practical training	
	Experimental work		Report		Laboratory attendance	1
	Essay		Seminar essay	1.5	Independent work	1.7
	Tests	0.2	Oral exam		Preparation for laboratory work	0.5
	Written exam	0.1	Project		(Other)	

Grading and evaluating student work in class and at the final exam	During semester students get independent assignments which should be presented in last week of semester. Grade (in percentage) is formed according to the formula: Grade(%) = 0,05 NP + 0,1 LV + 0,85 IA the activities in percentage: • NP - attendance at lectures, • LV – laboratory assessment, • IA – independent assigment.

Required literature (available in the library and via other media)	**Title**	**Number of copies in the library**	**Availability via other media**
	O. Bego: Predavanja iz predmeta Ugradbeni računalni sustavi, FESB		e-learning portal

Optional literature (at the time of submission of study programme proposal)	
Quality assurance methods that ensure the acquisition of exit competences	- Evaluation of results in accordance with the above learning outcomes - Feedback from students via surveys - Self-evaluation of teachers, - Institutional and non-institutional evaluations
Other (as the proposer wishes to add)	

NAME OF THE COURSE	SEMICONDUCTOR POWER CONVERTERS						
Code	FENI14	Year of study	1.				
Course teacher	BožoTerzić, Ph.D., Full Professor	Credits (ECTS)	6				
Associate teachers	Goran Majić, Ph.D.	Type of instruction (number of hours)	L	S	AE	LE	DE
			30	0	0	30	0
Status of the course	Obligatory	Percentage of application of e-learning	0				

COURSE DESCRIPTION

Course objectives	Training students for: - understanding the topologies and working principle of semiconductor power converters - permanent adoption and deepening of knowledge in the field of power converter
Course enrolment requirements and entry competences required for the course	Entry competences: - Basic knowledge of the course Power Electronics
Learning outcomes expected at the level of the course (4 to 10 learning outcomes)	Students will be able to: - select the type and ratings of power converter for defined applications, - parametrize and put into operation power converter in simpler application, - simulate power converter selected configuration in software package MATLAB, - measure and analyze the converter voltage and current waveforms in the time and frequency domain, - design power and control circuit of power converter with IGBT power switch, - predict and analyse impact of the power converter to the grid.

Course content broken down in detail by weekly class schedule (syllabus)

Course content	L hours	AE hours
Introduction. Areas of application of power converters. The divisions of the converter to the input / output variables. Basic topologies. The characteristics of semiconductor components used in power converters.	2	0
Direct (galvanic non isolated) dc converters: step up, step down, step up/down, bridge circuit. Indirect (galvanic isolated) dc converters: the forward and bridge circuit. The influence of the dead time to the output voltage.	2	0
Four-quadrant thyristor converter for DC drive. High-voltage thyristor converter, application for DC power transmission. Improving the power factor and reduce the current harmonics with thyristor converter.	2	0
AC voltage converters. Thyristor circuit breakers (on-off control). The phase voltage control. Applications: Soft-start of the induction motors, static VAR compensation.	2	0
Inverters. Single-phase inverter in a bridge configuration. Pulse width modulation techniques: one pulse, multi pulse, sine and modified sine wave modulation. Closed-loop control.	2	0
Three-phase voltage source six pulse inverter. Space vector modulation. Three-phase current source inverter.	2	0
Multilevel inverters. Diode clamped multilevel inverter, Flying capacitor multilevel inverter, Cascaded multilevel inverter.	2	0

	First midterm exam		
	Voltage source PWM rectifier with IGBT switches and LCL filter. Voltage oriented control in synchronous rotating coordinates. The filter resonance effect.	2	0
	Power converter in wind power plants. Basic topology and control structure of the converterr for asynchronous, synchronous and permanent magnet generators.	2	0
	Power converters in solar power plants. The characteristics of photovoltaic systems. The basic topology of the converters for photovoltaic systems.	2	0
	Drivers for thyristor and IGBT transistor. Overvoltage and short-circuit protection for converter with IGBT transistors.	2	0
	Electromagnetic compatibility of power converters. Type of electromagnetic interference and measures for their mitigation.	2	0
	Designing power circuit of converter with IGBT module. Microprocessor control of power converter.	2	0
	Second midterm exam		
	List of laboratory exercises		LE hours
	Simulation of dc/dc step-up and step-down converters		3
	Measurement and analysis of voltage and current waveforms of dc/dc step-up converter		3
	Simulation of three-phase four-quadrant thyristor converter		3
	Measurement and analysis of voltage and current waveforms of three-phase thyristor converter		3
	Simulation of three-phase vector controlled inverter		3
	Microprocessor control of three phase inverter		3
	Simulation of three-phase PWM rectifier with LCL filter		3
	Measurement and analysis of voltage and current waveforms of three-phase PWM rectifier		3
	Simulation of induction motor supplied by inverter and sine filter		3
	Frequency characteristics of three-phase inverter with and without sine filter		3

Format of instruction	☒ lectures ☐ seminars and workshops ☒ exercises ☐*on line* in entirety ☐ partial e-learning ☐ field work	☐ independent assignments ☒ multimedia ☒ laboratory ☐ work with mentor ☐ (other)
Studentresponsibilities	The presence on lectures in the amount of at least 70 % of the times scheduled. Performed all required laboratory exercises.	

Screening student work *(name the proportion of ECTS credits for eachactivity so that the total number of ECTS credits is equal to the ECTS value of the course)*	Class attendance	1	Research		Practical training	
	Experimental work		Report		Individual work	2,3
	Essay		Seminar essay		Laboratory exercises	1
	Tests	0,2	Oral exam	0.5	Preparation for laboratory exercises	1
	Written exam		Project		(Other)	

Grading and evaluating student work in class and at the final exam	There is one midterm exam after 7 weeks of lecturing. The second part of the exam is taken orally on the final exam. Midterm test is carried out as written test and lasts 90 minutes, and it consists of 10 theoretical questions and numerical problems. The requirement for passing grade is the positive assessment of laboratory exercises, 50

	% points on midterm exam and the positive assessment of oral exam. Final grade (in percentage) is formed according to the formula: Grade(%) = 0,2 LV + 0,3 MT + 0.5 OE where the activities in percentage: • LV – laboratory assessment, • MT – midterm test result, • OE – oral exam result The final grade is determined according to the following criteria: • 50-62% - sufficient (2) • 63-75% - good (3) • 76-88% - very good (4) • 89-100% - excelent (5) Students who did not pass the exam after two final exams take a makeup exam in the autumn period according to the same way as the final exam, i.e. written exam for first part of course and oral exam for the second one. The final grade is obtained by the same criteria as for twofinalexams.		
Required literature (available in the library and via other media)	**Title**	**Number of copies in the library**	**Availability via other media**
	1. B. Terzić: Authorized lectures, FESB		e-learning portal
Optional literature (at the time of submission of study programme proposal)	1. Flegar: Elektroničkienergetskipretvarači, Kigen, Zagreb, 2010. 2. T. Brodić: Osnoveenergetskeelektronike – poluvodičkienergetskipretvarači, Zigo, Rijeka 3. M.H. Rashid: Power Electronics – Circuits, Devices and Applications, Pearson Prentice Hall, USA, 2004. 4. Bose, B.K.: Power Electronics andVariableDrives, IEEE Press, New York, 1997.		
Quality assurance methods that ensure the acquisition of exit competences	- Evaluation of results in accordance with the above learning outcomes - Feedback from students via surveys - Self-evaluation of teachers - Institutional and non-institutional evaluations		
Other (as the proposer wishes to add)			

<table>
<tr><td>NAME OF THE COURSE</td><td colspan="8">MEASUREMENTS OF PROCESS QUANTITIES</td></tr>
<tr><td>Code</td><td>FENI19</td><td>Year of study</td><td colspan="6">1.</td></tr>
<tr><td>Course teacher</td><td>Goran Petrović, Ph.D., Associate Professor</td><td>Credits (ECTS)</td><td colspan="6">6</td></tr>
<tr><td rowspan="2">Associate teachers</td><td rowspan="2">Juraj Alojzije Bosnić, assistant</td><td rowspan="2">Type of instruction (number of hours)</td><td>L</td><td>S</td><td>AE</td><td>LE</td><td colspan="2">DE</td></tr>
<tr><td>30</td><td>0</td><td>0</td><td>30</td><td colspan="2">0</td></tr>
<tr><td>Status of the course</td><td>Obligatory</td><td>Percentage of application of e-learning</td><td colspan="6">0</td></tr>
<tr><td colspan="9">COURSE DESCRIPTION</td></tr>
<tr><td>Course objectives</td><td colspan="8">Training students for:
- signal conditioning and analogue processing of signals
- measuring of different kinds of process variables</td></tr>
<tr><td>Course enrolment requirements and entry competences required for the course</td><td colspan="8">None</td></tr>
<tr><td>Learning outcomes expected at the level of the course (4 to 10 learning outcomes)</td><td colspan="8">Students will be able to:
- make basic circuits for analogue processing,
- use the basic protocols for communication between smart sensors and PC,
- make temperature sensors calibration,
- use thermal imaging camera,
- make force and pressure sensors calibration,
- recommend appropriate sensors for displacement, temperature, force, pressure, velocity, level, flow, light, …
- make Labview program for monitoring, control and data acquisition.</td></tr>
<tr><td rowspan="11">Course content broken down in detail by weekly class schedule (syllabus)</td><td colspan="6">Course content</td><td>L hours</td><td>AE hours</td></tr>
<tr><td colspan="6">Instrument accuracy and parameters that affect an instrument’s performance. Static features of sensors.</td><td>2</td><td>0</td></tr>
<tr><td colspan="6">Dynamic features of sensors Transfer functions and frequencies responses of first and second order systems.</td><td>2</td><td>0</td></tr>
<tr><td colspan="6">Operation amplifier and signal conditioning. Amplification, summation, integration, derivation and filtering of analog signals.</td><td>2</td><td>0</td></tr>
<tr><td colspan="6">Transfer signals on long distances. Analog and digital modulations techniques.</td><td>2</td><td>0</td></tr>
<tr><td colspan="6">Interfaces for signal transferring (USART, RS232, RS 485). Communication protocols (HART, M Bus, MODBUS, Ethernet)</td><td>2</td><td>0</td></tr>
<tr><td colspan="6">Displacement sensors. Potentiometric, inductive, capacitive, ultrasound, optical, magnetostrictive, magnetoresistive. Hall effect sensors.</td><td>2</td><td>0</td></tr>
<tr><td colspan="6">Measuring of thermal quantities. Resistance thermometers. Thermistors. Linearization.</td><td>2</td><td>0</td></tr>
<tr><td colspan="6">First midterm exam</td><td></td><td>0</td></tr>
<tr><td colspan="6">Thermoelectric effects. Thermocouples. Pyroelectric effects. Thermal radiation. Thermography.</td><td>2</td><td>0</td></tr>
<tr><td colspan="6">Pressure measurements. Diaphragms, Bourdon tubes. Microphones. Force and moment measurements. Strain gauges. Piezo electric transducers. Charge amplifier.</td><td>2</td><td>0</td></tr>
</table>

	Velocity measurements. Doppler effect. Angular velocity. Incremental and absolute encoder. Accelerometers and vibrations.	2	0
	Level measurements. Direct level sensing. Indirect level sensing. Flow measurement. Bernoulli equation.	2	0
	Flow measurement instruments: Pitot tube, Orifice plate, Venturi tube, Rotameter, Turbine meter, Electromagnetic.	2	0
	Moisture and humidity. Photometric quantities: Luminous intensity. Luminous flux. Illuminance.	2	0
	Second midterm exam		0
	List of laboratory exercises		LE hours
	Principles of Labview coding (Data type, Input output variables)		3
	Loops and structures in Labview. Creating graphical user interface.		3
	Static characteristics of transducers. (Displacement and temperature)		3
	Thermistor and thermocouple. Linearization.		3
	Thermography. Measurement of thermal flux.		3
	Pressure, force, velocity and level measurement		3
	Educational Laboratory Virtual Instrumentation Suite (signal conditioning)		3
	Educational Laboratory Virtual Instrumentation Suite (photometry)		3
	Practical skills exam		2

Format of instruction	☒ lectures ☐ seminars and workshops ☒ exercises ☐*on line* in entirety ☐ partial e-learning ☐ field work	☐ independent assignments ☒ multimedia ☒ laboratory ☐ work with mentor ☐ (other)
Studentresponsibilities	The presence on lectures in the amount of at least 70 % of the times scheduled. Performed all required laboratory exercises.	

Screening student work *(name the proportion of ECTS credits for eachactivity so that the total number of ECTS credits is equal to the ECTS value of the course)*	Class attendance	1	Research		Practical training	
	Experimental work		Report		Individual work	3
	Essay		Seminar essay		Laboratory exercises	0,5
	Tests	0,5	Oral exam		Preparation for laboratory exercises	0,5
	Written exam	0,5	Project		(Other)	

Grading and evaluating student work in class and at the final exam	There are two midterms and final exams that are carried out as written tests. The first midterm exam is after 7 weeks of lecturing and the second one is after the next 6 weeks. Each midterm test consists of 10 theoretical questions and numerical problems and final tests consist of 20 theoretical questions and numerical problems. In the final exams students that did not pass the midterm exams take part. The requirement for passing grade is the positive assessment of laboratory exercises and 40 % points on each midterm exam or the final exam. Grade (in percentage) is formed according to the formula: Grade(%) = 0,4 LV + 0,3 (M1 + M2) the activities in percentage: • LV – laboratory assessment, • M1, M2 – test results.

Required literature (available in the library and via other media)	**Title**	**Number of copies in the library**	**Availability via other media**
	G. Petrović: Skripta s predavanja, FESB		e-learning portal
Optional literature (at the time of submission of study programme proposal)	Alan S. Morris: Measurement and Instrumentation Principles. Butterworth-Heinemann, Oxford. 2001. William C. Dunn: Fundamentals of Industrial Instrumentation and Process Control, McGraw-Hill, 2005.		
Quality assurance methods that ensure the acquisition of exit competences	- Evaluation of results in accordance with the above learning outcomes - Feedback from students via surveys - Self-evaluation of teachers Institutional and non-institutional evaluations		
Other (as the proposer wishes to add)			

NAME OF THE COURSE	**AUTOMATED ELECTRICAL DRIVES**						
Code	FENI16	Year of study	2.				
Course teacher	Božo Terzić, Ph.D., Full Professor	Credits (ECTS)	4				
Associate teachers	Goran Majić, Ph.D.	Type of instruction (number of hours)	L	S	AE	LE	DE
			30	0	0	15	0
Status of the course	Elective	Percentage of application of e-learning	0				
COURSE DESCRIPTION							
Course objectives	Training students for: - understanding the structure and operation principle of modern electric drives - permanent deepening of knowledge in the field of electric drives						
Course enrolment requirements and entry competences required for the course	Entry competences: - Basic knowledge of the course Electric Drives - Basic knowledge of the course Power Electronics - Basic knowledge of the course Elements of Industrial Plant Automation						
Learning outcomes expected at the level of the course (4 to 10 learning outcomes)	Students will be able to: - select the type, power and speed of the motor for defined working cycle, - select cross-section and type of power cables based on calculation of short circuit current and voltage drop in plant, - design and select protection devices of electric drives, - use specialized software package for design electric drives - commissioning electrical drives with power converter						

	- compare and rank drive converter characteristics of different world producers based on data from technical documentation		
Course content broken down in detail by weekly class schedule (syllabus)	Course content	L hours	AE hours
	The basic structure and components of the controlled and uncontrolled electrical drives. Classification and features of modern electric drives according to product range of the world's largest manufacturer of electric drives (ABB, SIEMENS). Electrical drives in automation systems.	2	0
	Design electric drives. Legislation. Preliminary, main and detailed project. An example of the main electrical engineering project with automated electric drive.	2	0
	Basic classification and features of working mechanisms in electric drives. Determination of power and speed of the motor based on the defined duty cycle. Example - elevator in the building.	2	0
	Select the motor for electric drives: type, power, speed, IP protection, cooling, mounting arrangements, thermal protection.	2	0
	Select power converter for electric drives: basic topology, input and output filters, analogue and digital input/output, encoder inputs, communication link, programming tools.	2	0
	Determination of the type and cross-section of the power cables based on calculation of load, voltage drop and short-circuit current.	2	0
	Type of the protection and switching device in electric drives (fuse, circuit-breaker, thermistor, contactor, bimetallic protection). Select the protection devices for electric drives with and without power converter.	2	0
	Presentation of student seminars.		
	Electromagnetic compatibility (EMC) in electric drives. Du/dt, sine and RFI filter. Motor bearing currents and measures to eliminate these currents.	2	0
	Commissioning of the electric drives with power converters.	2	0
	Monitoring, visualisation and diagnostics in automated electric drives.	2	0
	Industrial communications in modern electric drives: Profibus, Ethernet, Modbus, CAN	2	0
	Examples of modern electric drives: automated electric drives for crane applications with slip-rings induction motor and thyristor voltage controller.	2	0
	Examples of modern electric drives: automated electric drives for crane applications with squirrel cage induction motor and four-quadrant IGBT frequency converter.	2	0
	Presentation of students' practical work.		
	List of laboratory exercises		LE hours
	Selection of motor for electric vehicles based on defined duty cycles		3
	Design power supply circuit of electric drives by program package "Ecodial".		6
	Converter parameter settings and commissioning of the electric drives for crane application with squirrel cage induction motor and four-quadrant IGBT frequency converter		3
	Converter parameter settings and commissioning of the electric drives for crane application with with slip-rings induction motor and thyristor voltage controller.		3

<table>
<tr><td>Format of instruction</td><td colspan="3">☒ lectures
☐ seminars and workshops
☒ exercises
☐ on line in entirety
☐ partial e-learning
☐ field work</td><td colspan="3">☒ independent assignments
☒ multimedia
☒ laboratory
☐ work with mentor
☐ (other)</td></tr>
<tr><td>Student responsibilities</td><td colspan="6">The presence on lectures in the amount of at least 70 % of the times scheduled.
Performed all required laboratory exercises.</td></tr>
<tr><td rowspan="5">Screening student work (name the proportion of ECTS credits for each activity so that the total number of ECTS credits is equal to the ECTS value of the course)</td><td>Class attendance</td><td>1</td><td>Research</td><td></td><td>Practical training</td><td></td></tr>
<tr><td>Experimental work</td><td></td><td>Report</td><td></td><td>Individual work</td><td>1</td></tr>
<tr><td>Essay</td><td></td><td>Seminar essay</td><td>1</td><td>Laboratory exercises</td><td>0.5</td></tr>
<tr><td>Tests</td><td></td><td>Oral exam</td><td></td><td>Preparation for laboratory exercises</td><td>0.5</td></tr>
<tr><td>Written exam</td><td></td><td>Project</td><td></td><td>(Other)</td><td></td></tr>
<tr><td>Grading and evaluating student work in class and at the final exam</td><td colspan="6">During the first part of the semester, each student has an independent seminar work from the design of electrical drive with a frequency converter and asynchronous motor. Seminar presents in front of other students, assistants and teachers. The rating of the seminar is the first part of the exam. The second part of the exam is taken at the end of the semester as practical work in which the students put into operation the drive with power converter. The requirement for passing grade is the positive assessment of seminar and practical work. Final grade (in percentage) is formed according to the formula:
Grade(%) = 0,5 SW + 0.5 PW
where the activities in percentage:
• SW – seminar work grade,
• PW – practical work grade,
The final grade is determined according to the following criteria:
• 50-62% - sufficient (2)
• 63-75% - good (3)
• 76-88% - very good (4)
• 89-100% - excelent (5)

Students who did not pass the exam after two final exams take a makeup exam in the autumn period according to the same way as the final exam. The final grade is obtained by the same criteria as for two final exams.</td></tr>
<tr><td rowspan="2">Required literature (available in the library and via other media)</td><td colspan="4">Title</td><td>Number of copies in the library</td><td>Availability via other media</td></tr>
<tr><td colspan="4">• B. Terzić: Authorized lectures, FESB</td><td></td><td>e-learning portal</td></tr>
<tr><td>Optional literature (at the time of submission of study programme proposal)</td><td colspan="6">• http://www.abb.com
• http://www.siemens.com</td></tr>
<tr><td>Quality assurance methods that ensure</td><td colspan="6">- Evaluation of results in accordance with the above learning outcomes
- Feedback from students via surveys</td></tr>
</table>

the acquisition of exit competences	- Self-evaluation of teachers - Institutional and non-institutional evaluations
Other (as the proposer wishes to add)	

NAME OF THE COURSE	ENERGY STORAGE SYSTEMS						
Code	FENI41	Year of study	2.				
Course teacher	Ozren Bego, Ph.D., Associate Professor	Credits (ECTS)	4				
Associate teachers	Danijel Jolevski, Ph.D., Assistant Professor	Type of instruction (number of hours)	L	S	AE	LE	DE
			30	0	0	15	0
Status of the course	Elected	Percentage of application of e-learning	0				

COURSE DESCRIPTION

Course objectives	Training students for: - understanding terms and concepts of different energy storage systems, - selection of energy storage system regard to technical, technological and economical aspects, - analyse of advanced store system functions in order to stabilize electrical grid.
Course enrolment requirements and entry competences required for the course	None
Learning outcomes expected at the level of the course (4 to 10 learning outcomes)	Students will be able to: - analyse needs for energy storage, - select energy storage technology according to requirements from grid system, - build mathematical model of: • battery based energy storage, • impact of energy store on grid - define requirements on energy storage advanced functions

Course content broken down in detail by weekly class schedule (syllabus)

Course content	L hours	AE hours
Energy storage – concept, technologies, applications	2	
Application of energy storage system in grid stabilization. Especial overview on applications in weak and isolated grids, microgrids.	2	
Separation and overview of storage technologies on short-term and long- term systems.	2	
Techno-economical aspects of energy storage implementation.	2	

	Thermal energy storage. Compressed air energy storage (CAES).	2	
	Mechanical energy storage: with potential energy (reversible hydro power plants) and kinetic energy (flywheel).	2	
	Reversible chemical reaction for energy storage: hydrogen and methane.	2	
	Energy storage in electromagnetic systems. Construction and application of supercapatitors. Application in electric vehicles.	2	
	Electrochemical energy storage: batteries. Technology and characteristics	2	
	Supervision of battery state of charge (SOC), SOC estimators, hardware for battery monitoring.	2	
	Battery based energy storage application in grid stabilization. Concept of whole system (battery, monitoring, connection to grid, grid state supervision)	2	
	Active devices for connecting battery storage to grid: active front end (AFE).	2	
	Applications in grid stabilization: load levelling, rotating reserve, UPS, voltage regulation,…	2	
	List of laboratory exercises		LE hours
	Supercapacitors – modelling		3
	Supercapacitors – monitoring system		3
	Batteries – modelling		3
	Batteries – monitoring SOC		3
	Presentation of independent assignments		3

Format of instruction	☒ lectures ☐ seminars and workshops ☒ exercises ☐*on line* in entirety ☐ partial e-learning ☐ field work	☒ independent assignments ☐ multimedia ☒ laboratory ☐ work with mentor ☐ (other)
Studentresponsibilities	The presence on lectures in the amount of at least 70 % of the times scheduled. Performed all required laboratory exercises.	

Screening student work *(name the proportion of ECTS credits for eachactivity so that the total number of ECTS credits is equal to the ECTS value of the course)*	Class attendance	1	Research		Practical training	
	Experimental work		Report		Individual work	1
	Essay		Seminar essay	1	Laboratory exercises	0,5
	Tests	0	Oral exam	0,5	Preparation for laboratory exercises	
	Written exam	0	Project		(Other)	

Grading and evaluating student work in class and at the final exam	During semester students get independent assignments which should be presented in last week of semester. After that oral exam will be done. Final grade (in percentage) is formed according to the formula: Grade(%) = 0,4 IA + 0,6 OE the activities in percentage: • IA – independent assignments, • OE – oral exam.

Required literature (available in the	**Title**	**Number of copies in the library**	**Availability via other media**

library and via other media)	O. Bego: Predavanja iz predmeta Sustavi za pohranu energije		e-learning portal
Optional literature (at the time of submission of study programme proposal)	Robert A. Huggins: Energy storage, Springer, 2010.		
Quality assurance methods that ensure the acquisition of exit competences	- Evaluation of results in accordance with the above learning outcomes - Feedback from students via surveys - Self-evaluation of teachers - Institutional and non-institutional evaluations		
Other (as the proposer wishes to add)			

<table>
<tr><td>NAME OF THE COURSE</td><td colspan="7">POWER PLANTS</td></tr>
<tr><td>Code</td><td>FENI08</td><td>Year of study</td><td colspan="5">1</td></tr>
<tr><td>Course teacher</td><td>Elis Sutlović, Ph.D. FullProfessor</td><td>Credits (ECTS)</td><td colspan="5">6</td></tr>
<tr><td rowspan="2">Associate teachers</td><td rowspan="2">Josip Vasilj, Ph.D.</td><td rowspan="2">Type of instruction (number of hours)</td><td>L</td><td>S</td><td>AE</td><td>LE</td><td>DE</td></tr>
<tr><td>45</td><td>0</td><td>0</td><td>15</td><td>0</td></tr>
<tr><td>Status of the course</td><td>Obligatory</td><td>Percentage of application of e-learning</td><td colspan="5">0</td></tr>
<tr><td colspan="8">COURSE DESCRIPTION</td></tr>
<tr><td>Course objectives</td><td colspan="7">Training students for:
- acquisition of advanced knowledge about the process of converting various forms of energy into electricity,
- detailed knowledge about the main components and about various solutions of power plants,
- deepening of knowledge about the properties, advantages and disadvantages as well as the operating parameters of different types of power plants.</td></tr>
<tr><td>Course enrolment requirements and entry competences required for the course</td><td colspan="7">None</td></tr>
<tr><td>Learning outcomes expected at the level of the course (4 to 10 learning outcomes)</td><td colspan="7">Students will be able to:
1. Explain the process of energy conversion into steam turbine power plants, gas turbine power plants and in combined-cycle power plants.
2. Describe conversion processes in nuclear power plants.
3. Compare and choose the most suitable type and appropriate solution of thermal power plant under given conditions.</td></tr>
</table>

	4. Determine the optimal basic parameters of hydroelectric power plant according to capability of water flow. 5. Select solution of hydroelectric power plant for given conditions, propose preliminary design and specify the fundamental characteristics of main equipment. 6. Design, compare and explain the different solutions of power plant circuit diagrams.		
Course content broken down in detail by weekly class schedule (syllabus)	Course content		L hours
	Repetition: classification of energy forms, conversion of energy forms into electricity. The basic characteristics of the production and consumption of electricity. Types and classification of power plants. Structure of Croatian power system.		3
	A review of fundamental thermodynamic principles, thermodynamic properties, and the thermodynamic laws.		3
	Cycles of open and closed systems. Conversion of the aggregation state.		3
	Steam-electric power station: steam power cycles, Rankine cycle, methods to increase the efficiency of the Rankine cycle, combined heat and power generation.		3
	Main components on steam power plants: steam turbines, boilers with the system of removal and treatment of combustion gases, condensers		3
	Gas turbine power plants, Combined-cycle power plants, Nuclear power plants		3
	Thermal power plant control. Energy characteristics of thermal power plant. Environmental impacts of thermal power plants. The EU Emissions Trading System.		3
	First midterm exam		
	Basic characteristics and types of hydroelectric power plants. The main components of HPP.		3
	Water turbines: The characteristics of certain types of water turbines; Power losses in the turbine; Principles of similarity and specific speed of a turbine; Cavitation; Application range for water turbines; Rotational speed selection.		3
	Water flow analysis. Energy characteristics of HPP. Advantages and disadvantages of HPP. Environmental impacts of HPP.		3
	Wind power plants. Photovoltaic power plants.		3
	Power plant single line diagrams. The characteristics of electric generators. PQ diagram.		3
	Basic concept and application of generator protection		3
	Second midterm exam		
	List of laboratory exercises		LE hours
	Circuit for control and monitoring of a synchronous generator in power plant		3
	Circuit for protection of a synchronous generator in power plant		3
	Excitation in power plant generators		3
	Single-line diagram of the main circuits and single-line diagrams of own consumption in the HPP Zakučac		3
	Visit and tour of the HPP Zakučac		3
Format of instruction	☒ lectures ☐ seminars and workshops ☐ exercises	☐ independent assignments ☐ multimedia ☒ laboratory	

<table>
<tr><td></td><td colspan="4">☐on line in entirety
☐ partial e-learning
☐ field work</td><td colspan="2">☐ work with mentor
☐ (other)</td></tr>
<tr><td>Studentresponsibilities</td><td colspan="6">The presence on lectures in the amount of at least 70 % of the times scheduled.
Performed all required laboratory exercises.</td></tr>
<tr><td rowspan="5">Screening student work (name the proportion of ECTS credits for eachactivity so that the total number of ECTS credits is equal to the ECTS value of the course)</td><td>Class attendance</td><td>1,5</td><td>Research</td><td></td><td>Practical training</td><td></td></tr>
<tr><td>Experimental work</td><td></td><td>Report</td><td></td><td>Individual work</td><td>3</td></tr>
<tr><td>Essay</td><td></td><td>Seminar essay</td><td></td><td>Laboratory exercises</td><td>0,5</td></tr>
<tr><td>Tests</td><td>0,3</td><td>Oral exam</td><td></td><td>Preparation for laboratory exercises</td><td>0,5</td></tr>
<tr><td>Written exam</td><td>0,2</td><td>Project</td><td></td><td>(Other)</td><td></td></tr>
<tr><td>Grading and evaluating student work in class and at the final exam</td><td colspan="6">There are two midterms and final exams. The first midterm exam is after 7 weeks of lecturing and the second one is after the next 6 weeks. Each midterm test consists of 6 theoretical questions and final tests consist of 10 theoretical questions. In the final exams students that did not pass the midterm exams take part. The midterm and final exams are carried out as written tests. The requirement for passing grade is the positive assessment of laboratory exercises and 50 % points on each midterm exam or the final exam.
Grade (in percentage) is formed according to the formula:
$$\text{Grade}(\%) = 0{,}05\,(AL + LA) + 0{,}45\,(M1 + M2)$$
the activities in percentage:
AL - attendance at lectures,
LA – laboratory assessment,
M1, M2 – test results.
The final grade is determined as follows:

<u>Percentage</u> <u>Description</u>
50% do 61% Sufficient (2)
62% do 74% Good (3)
75% do 87% Very Good (4)
88% do 100% Excellent (5)</td></tr>
<tr><td rowspan="3">Required literature (available in the library and via other media)</td><td colspan="4">Title</td><td>Number of copies in the library</td><td>Availability via other media</td></tr>
<tr><td colspan="4">1. H. Požar: Osnoveenergetike, svezak I, II i III, Školskaknjiga, Zagreb 1992,</td><td>10</td><td></td></tr>
<tr><td colspan="4">2. E. Sutlović: Predavanja, FESB</td><td></td><td>e-learning portal</td></tr>
<tr><td>Optional literature (at the time of submission of study programme proposal)</td><td colspan="6">- Požar, H.: Proizvodnjaelektričneenergije, I i II dio, skripta, ETF, Zagreb, 1966.
- Pilić-Rabadan LJ., Stipaničev D., Milas Z.: Hidroenergetska i aeroenergetskapostrojenja, Školskaknjiga Zagreb, 1996.</td></tr>
<tr><td>Quality assurance methods that ensure the acquisition of exit competences</td><td colspan="6">- Evaluation of results in accordance with the above learning outcomes
- Feedback from students via surveys
- Self-evaluation of teachers
- Institutional and non-institutional evaluations</td></tr>
</table>

Other (as the proposer wishes to add)	

NAME OF THE COURSE	**PROTECTION AT SUBSTATIONS**						
Code	FENI10	Year of study	2				
Course teacher	Petar Sarajčev, Ph.D.,Full Professor	Credits (ECTS)	7				
Associate teachers		Type of instruction (number of hours)	L	S	AE	LE	DE
			45			15	
Status of the course	Obligatory	Percentage of application of e-learning	0				

COURSE DESCRIPTION

Course objectives	Training students for: - understandingbasicprinciplesofpower system protection - permanentadoptionofprinciplesofdistribution network relayprotection design - permanentadoptionoftransformerprotection design - settingupandsolvingtransformerdifferentialprotectionproblems - understandingprinciplesof distance protection
Course enrolment requirements and entry competences required for the course	CompletedUndergraduatecourseofElectricalengineeringandinformationtechnology
Learning outcomes expected at the level of the course (4 to 10 learning outcomes)	Students will be able to: - calculateandselectcurrenttransformers for relayprotectionapplications - design protectionofdistribution network consideringitsneutralpointtreatment - calculatedistribution network relayprotectionfunctionsettings - design protectionofpowertransformers (twoandthreewindings) - selectappropriatenumericalrelays for transformerprotection - calculateprotectionsettingsof distance relays

Course content broken down in detail by weekly class schedule (syllabus)	Course content	L or S hours	AE hours
	Treatment of neutral point earthing in distribution networks. Short-circuit calculations overview. Earth fault. Petersen coil.	6	
	Currentandvoltagetransformers, Toroidtransformers	3	
	Distributionneworkrelayprotectionfundamentals. Overcurrentprotection, Earth-faultprotection, Overvoltageprotection, Directionalprotection	6	
	Relayprotectionininsulateddistributionnetworks, Protection ofneutralearthingresistor, Busbarprotection	6	

	Power transformerrelayprotection, Differentialprotection, REF protection, Thermalprotection, Overcurrentprotection, Reverse interlocking	6	
	Transmission network relayprotectionfundamentals, Distance protection, In-feedcompensation, Impedancemeasurement, Quadrilateralprotectioncharacteristic, Power swingblocking	6	
	Teleprotectionschemes, Breakerfailure	3	
	List oflaboratoryor design exercises		LE or DE hours
	Electromechanical, staticandnumericalprotectionrelays, Testingprotectionrelayfunctions		3
	DIGSI software packageby Siemens for protectionrelaysettings		6
	SIGRA software packageby Siemens for post-mortem analysis		3
	Visit to the GIS substationand live interactionwithprotectionrelays		3

Format of instruction	☒lectures ☐seminars and workshops ☒exercises ☐*on line*in entirety ☐partial e-learning ☐field work	☐independent assignments ☒multimedia ☒laboratory ☐work with mentor ☐ (other)
Studentresponsibilities		

Screening student work *(name the proportion of ECTS credits for eachactivity so that the total number of ECTS credits is equal to the ECTS value of the course)*	Class attendance	2,5	Research		Practical training	
	Experimental work		Report		Individual work	2,5
	Essay		Seminar essay		Laboratory excercises	1,0
	Tests	0,5	Oral exam		(Other)	
	Written exam	0,5	Project		(Other)	

Grading and evaluating student work in class and at the final exam	There are two midterms and final exams. The first midterm exam is after 7 weeks of lecturing and the second one is after the next 6 weeks. Each midterm test consists of 10 theoretical questions and numerical problems and final tests consist of 10 theoretical questions and numerical problems. In the final exams students that did not pass the midterm exams take part. The midterm and final exams are carried out as written tests. The requirement for passing grade is the positive assessment of laboratory exercises and 50% points on each midterm exam or the final exam. Grade (in percentage) is formed according to the formula: Grade(%) = 0,5 (M1 + M2) the activities in percentage: M1, M2 – test results.

Required literature (available in the library and via other media)	**Title**	**Number of copies in the library**	**Availability via other media**
	P. Sarajčev, Autorizirana predavanja, FESB		e-learning portal

Optional literature (at the time of submission of study programme proposal)	- P. M. Anderson, Power system protection, IEEE Press, New York, 1999.
Quality assurance methods that ensure	- Evaluation of results in accordance with the above learning outcomes - Feedback from students via surveys

the acquisition of exit competences	- Self-evaluation of teachers - Institutional and non-institutional evaluations
Other (as the proposer wishes to add)	

NAME OF THE COURSE	**LIGHTNING PROTECTION AND GROUNDING**						
Code	FENI23	Year of study	2.				
Course teacher	Slavko Vujević, Ph.D., Full Professor	Credits (ECTS)	4				
Associate teachers	Dino Lovrić, Ph.D., Research Assistant	Type of instruction (number of hours)	L	S	AE	LE	DE
			30	0	0	15	0
Status of the course	Elective	Percentage of application of e-learning	0				
COURSE DESCRIPTION							
Course objectives	Training students for understanding and application of specialized knowledge of: - lightning protection of structures, - lightning protection of electric power plants and transmission lines, - protection against atmospheric and switching surges, - grounding of electric power plants and transmission lines, - grounding systems.						
Course enrolment requirements and entry competences required for the course	None						
Learning outcomes expected at the level of the course (4 to 10 learning outcomes)	Students will be able to: - design a system for lightning protection of structures, - design a system for protection against lightning flashes to electric power plants and transmission lines, - design a system for overvoltage protection of electrical and electronic systems within a structure, - design a system for overvoltage protection of electric power plants and transmission lines, - measure the apparent resistivity of the soil, - interpret geoelectric sounding data by a computer program, - measure grounding resistance, touch voltage, step voltage and transferred potentials, - comment on methods for numerical modelling of grounding systems, - analyze the results of numerical modelling of grounding system.						
Course content broken down in detail by weekly	Course content	L hours					
	Lightning protection historical background. Isoceraunic level. Mechanisms of lightning. Types and polarity of lightning.	2					

class schedule (syllabus)	The most important data to protect against lightning. Impulse generators. International and national technical regulations and standards for lightning protection.	2
	Numerical modelling of electrical networks using finite element technique. Theoretical background of software package EMTP.	2
	The main content of the set of standards HRN EN 62305. The effects of lightning. Damages and losses on structures and services. Risk and risk components. Protective measures. Protective levels.	2
	Risk management in compliance with HRN EN 62305-2.	2
	Design of LPS system. Design of air-termination system. Active air-terminations - nonclassical LPS.	2
	Design of down-conductor system. Design of earth-termination system.	2
	The internal LPS. Overvoltage protection of internal systems. Coordinated overvoltage protection.	2
	Overvoltage protection of information technology systems. Overvoltage protection of data networks.	2
	The surges in electric power networks. Electrogeometric model. Lightning protection of transmission lines and electric power plants.	2
	The selection of features of metal oxide surge arresters. Lightning protection of low-voltage networks. Risk of electric shock. Touch voltage. Step voltage. Personal lightning protection.	2
	Interpretation of geoelectric sounding data. The measurement of the grounding resistance.	2
	Numerical modelling of grounding systems.	2
	Two midterm exams	
	List of laboratory exercises	LE hours
	Numerical modelling of electrical networks using software package EMTP-RV	3
	Numerical modelling of surge arrester using software package EMTP-RV	3
	Assessment of the risk due to lightning flashes to the structure	3
	Professional visit to electric power plants	6

Format of instruction	☒ lectures ☐ seminars and workshops ☐ exercises ☐*on line* in entirety ☐ partial e-learning ☐ field work	☐ independent assignments ☒ multimedia ☒ laboratory ☐ work with mentor ☐ (other)
Studentresponsibilities	Attendance on lectures in the amount of at least 70 % of the times scheduled. Performed all required laboratory exercises.	

Screening student work *(name the proportion of ECTS credits for eachactivity so that the total number of ECTS credits is equal to the ECTS value of the course)*	Class attendance	1.5	Research		Practical training	
	Experimental work		Report		Individual work	1.7
	Essay		Seminar essay		Laboratory exercises	0.4
	Tests	0.2	Oral exam		Preparation for laboratory exercises	0.1
	Written exam	0.1	Project		(Other)	

Grading and evaluating student work in class and at the final exam	There are two midterm exams. After two midterm exams, student can pass the entire exam. In the two final exams students take course parts that they did not pass in the preliminary exams. If in the first final exam student passes one of the

<table>
<tr><td></td><td colspan="3">two course parts, that course part the student does not have to take in the second final exam. The requirement for a positive evaluation of the course part is that the student has completed at least 50 % points from that course part. The final grade (in percentage) can be calculated using the formula:
Grade (%) = 0.1*LV + 0.45*(G1 + G2)
where activities in percentage are: LV - laboratory assessment, G1 - points from the first course part, G2 - points from the second course part.
Students who did not pass the entire exam after two final exams can pass the exam in two additional exams. In the two additional exams students take the entire course. The requirement for a positive assessment of the additional exams is that the student has completed at least 50 % points from the entire course. The final grade (in percentage) can be calculated using the formula:
Grade (%) = 0.1*LV + 0.9*G
where activities in percentage are: LV - laboratory assessment, G - points from the entire course.
The final grade can be calculated as follows:
• 50 % to 61 % - pass (2)
• 62 % to 74 % - good (3)
• 75 % to 87 % - very good (4)
• 88 % to 100 % - excellent (5)
Each of the midterm exams consists of ten theoretical questions. Two final exams and two additional exams consist of twenty theoretical questions.</td></tr>
<tr><td rowspan="3">Required literature (available in the library and via other media)</td><td>Title</td><td>Number of copies in the library</td><td>Availability via other media</td></tr>
<tr><td>Vujević, S.: "PredavanjaizpredmetaZaštitaodmunje i uzemljenje", Sveučilište u Splitu, FESB, Split, 2014. (lecture notes – electronic version)</td><td></td><td>e-learning portal</td></tr>
<tr><td>Hasse, P.; Wiesinger, J. and Zischank, W., "Priručnik za zaštituodmunje i uzemljenje", Kigen d.o.o., Zagreb, 2009.</td><td>5</td><td></td></tr>
<tr><td>Optional literature (at the time of submission of study programme proposal)</td><td colspan="3">• Padelin, M., "Zaštita od groma", Školskaknjiga, Zagreb, 1987.
• Corray, V. (editor), "Lightning Protection", IET, 2010.
• Kizilcay, M., Prikler, L., "ATP-EMTP Beginner's Guide for EEUG Members", European EMTP-ATP Users Group, 2000.</td></tr>
<tr><td>Quality assurance methods that ensure the acquisition of exit competences</td><td colspan="3">• Evaluation of results in accordance with the above learning outcomes
• Feedback from students via surveys
• Self-evaluation of teachers
• Institutional and non-institutional evaluations</td></tr>
<tr><td>Other (as the proposer wishes to add)</td><td colspan="3"></td></tr>
</table>

NAME OF THE COURSE	**SMART GRIDS**		
Code	FENI46	Year of study	5
Course teacher	Josip Vasilj, PhD	Credits (ECTS)	4
Associate teachers	Damir Jakus, PhD	Type of instruction (number of hours)	L: 30; S: ; AE: ; LE: 15; DE:
Status of the course	Elective	Percentage of application of e-learning	30

COURSE DESCRIPTION

Course objectives	Training students for: - Smart grid concepts - Microgrid concepts - Smart grids and Microgrids control - Smart grids and Microgrids protection - Understanding novel concepts in control and management - Application of novel control concepts in practical systems - Understanding mathematical optimization - Integration of optimization in control systems - Application of Python programming language in control systems
Course enrolment requirements and entry competences required for the course	None
Learning outcomes expected at the level of the course (4 to 10 learning outcomes)	Students will be able to: - Understand Smart grid and Microgrid concepts - Understand protection principles in Smart grids and Microgrids - Define and recognize modern control concepts - Recognize different systems and design appropriate control - Validate different control concpts

Course content broken down in detail by weekly class schedule (syllabus)

Course content	L or S hours	AE hours
1. Smart Grids and Micrograds - Introduction	4	
2. Architecture, control and protection in Smart grids and Micrograds	4	
3. Microgrid control issues	4	
4. Introduction to modern control systems – definitions. overview, development	4	
5. Optimal control theory – Optimization problems, Optimal control, KKT conditions, Numerical methods	2	
6. Model-predictive control	4	
7. Numerical solution to Model-predictive control	4	

List of laboratory or design exercises	LE or DE hours
1. Matlab introduction	2
2. Development of Smart grid Matlab model	3
3. Development of Microgird Matlab model	3
4. Model-predictive control in Matlab/Python	2

Format of instruction	☒ lectures	☒ independent assignments

<table>
<tr><td></td><td colspan="4">☐ seminars and workshops
☐ exercises
☐ on line in entirety
☐ partial e-learning
☐ field work</td><td colspan="2">☒ multimedia
☒ laboratory
☐ work with mentor
☐ (other)</td></tr>
<tr><td>Student responsibilities</td><td colspan="6">- The presence on lectures in the amount of at least 70 % of the times scheduled.
- Completed all required laboratory exercises.
- Completed and graded seminar work assignment.</td></tr>
<tr><td rowspan="5">Screening student work (name the proportion of ECTS credits for each activity so that the total number of ECTS credits is equal to the ECTS value of the course)</td><td>Class attendance</td><td>1</td><td>Research</td><td></td><td>Practical training</td><td></td></tr>
<tr><td>Experimental work</td><td></td><td>Report</td><td></td><td>Individual assignments</td><td>1</td></tr>
<tr><td>Essay</td><td></td><td>Seminar essay</td><td>0.5</td><td>Laboratory exercises</td><td>0.5</td></tr>
<tr><td>Tests</td><td>0.5</td><td>Oral exam</td><td></td><td>(Other)</td><td></td></tr>
<tr><td>Written exam</td><td>0.5</td><td>Project</td><td></td><td>(Other)</td><td></td></tr>
<tr><td>Grading and evaluating student work in class and at the final exam</td><td colspan="6">During the semester there will be one midterm exam covering lectures. The first midterm exam will be in the eighth week of summer semester. As a part of laboratory exercises students will be given their seminar assignments. Student can pass the class by passing midterm exam and by completing their seminar assignments. In the two final exams in February, students can pass reaming part(s) which they didn't pass through midterm exams.

Students who have failed to pass the class after two final exams can try to pass the subject by taking the disciplinary exam which is organized in first part of autumn term. The last chance to pass the subject is through commission exam which will be held in the second part of the autumn exam period. In autumn term the requirement for positive mark is that the student has at least 50% success on the exam as well as positive mark from seminar assignment.
The final score (in percentage) is formed on the basis of all activities according to the formula:

Grade (%) = 0,5xGk + 0,5xS
Grade (%) = 0,5xG + 0,5xS (for disciplinary and commission exam)

wherein:
• Gk - points obtained during midterms
• G - points obtained during exam
• S – point given for seminar assignment
The final grade is determined as follows:
Grade (%) — Mark
50 % do 6 1% — sufficient (2)
62 % do 74 % — good(3)
75 % do 87 % — very good(4)
88 % do 100 % — excellent(5)

Exam terms:
The first and second final exam: February
The disciplinary and commission exam: August / September

Under the Article 65 of the Faculty Statute, the student is required to participate in all forms of teaching and attend: lectures at least 70% of scheduled time and laboratory exercises 100% of scheduled time. If you do not meet these requirements, the student will not be able to take the examination.</td></tr>
</table>

Required literature (available in the library and via other media)	**Title**	**Number of copies in the library**	**Availability via other media**
	J. Vasilj: Smart Grids, lectures		e-learning
	Jakus, D., Krstulović Opara, J. : Obnovljivi izvori energije - upute za laboratorijske vježbe -, Split 2013.		e-learning
Optional literature (at the time of submission of study programme proposal)	- L. Freris, D.Infield: Renewable Energy in Power Systems, Wiley, 2008 - Microgrids Architectures and Control, Wiley, 2014 - R. Carbone: Energy Storage in the Emerging Era of Smart Grids, InTech, 2011..		
Quality assurance methods that ensure the acquisition of exit competences	- Keeping records of student class attendance - Annual review of the exam success - Feedback from students via surveys - Self-evaluation of teachers - Feedback on the subject relevance from the former students who have already graduated		
Other (as the proposer wishes to add)			