## DESCRIPTION OF THE COURSES

- Course code: ELR2111
- Course title: DIGITAL SIGNAL PROCESSING FOR PROTECTION AND CONTROL
- Language of the lecturer: English

| *Course form* | ***Lecture*** | ***Classes*** | ***Laboratory*** | ***Project*** | ***Seminar*** |
|---|---|---|---|---|---|
| *Number of hours/week** | *2* | | *1* | | |
| *Number of hours/semester** | *30* | | *15* | | |
| *Form of the course completion* | *Exam* | | *Pass/Reports* | | |
| ***ECTS credits*** | *4* | | *1* | | |
| ***Total Student's Workload*** | *120* | | *30* | | |

- Level of the course (basic/advanced): advanced
- Prerequisites:
  completed courses: Mathematics, Circuit Theory, Informatics
- Name, first name and degree of the lecturer/supervisor:
  Andrzej Wiszniewski, Prof., Ph. D., D. Sc.
- Names, first names and degrees of the team's members:
  Janusz Szafran, Prof., Ph. D., D. Sc.
  Waldemar Rebizant, Ph. D., D. Sc.
  Mirosław Łukowicz, Ph. D.
- Year: 1 Semester: 2
- Type of the course (obligatory/optional): obligatory
- Aims of the course (effects of the course):
  As an effect of the course completion the students are expected to present the knowledge on the theory of digital signal processing as applied to power system control and protection systems. The students should show the ability of chosing proper algorithms of signal processing for given practical problems encountered in power system protection and control.
- Form of the teaching (traditional/e-learning): traditional
- Course description:
  The course contains the basic problems and practical aspects of digital signal processing for power system protection and control. After an introduction and general theoretical and numerical basis, the following practical problems are presented: analog filtration, A/D conversion, digital filtration (FIR & IIR filters design and parameters), estimation of signal parameters (criterion values), decision making methods and algorithms, chosen algorithms of power system control, integrated measurement and control systems. A computer-based laboratory supplements the course.
- Lecture:

| *Particular lectures contents* | *Number of hours* |
|---|---|
| *1. Historical perspective, development of analog and digital power* | *2* |

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|---|---|
| *system control systems, reasons for and benefits of digital control, advantages of digital implementation.* | |
| 2. *Mathematical basis for control and protection algorithms: complex Fourier series, Fourier transforms.* | *2* |
| 3. *Discrete Fourier transform, Z-transform theorems, analog and discrete integration.* | *2* |
| 4. *Analog filters: standard low-pass approximations, frequency and time response of the filter, analog filter design, frequency band transformation.* | *2* |
| 5. *Analog to digital converters, multiplexer and analog memory, quantization time and errors, Shannon sampling theorem, practical sampling rates.* | *2* |
| 6. *Classification of digital filters, design of recursive filters using impulse invariant techniques.* | *2* |
| 7. *Design of recursive filters using frequency prewarping and the bilinear transformation, problems of quantization and round-off errors.* | *2* |
| 8. *Design of non-recursive digital filters using a window function, commonly used FIR filter window functions and associated frequency responses.* | *2* |
| 9. *Signal orthogonalization algorithms: single & double delay methods, FIR orthogonal filters, correlation.* | *2* |
| 10. *Signal magnitude estimation: digital integration methods, orthogonal components based methods, correlation, detailed algorithms.* | *2* |
| 11. *Measurement of other power system quantities: algorithms of estimation of active and reactive power, impedance components, signal phase, digital estimation of power system frequency and frequency deviation.* | *2* |
| 12. *Measurements in dynamic state of estimation, measurement error sources (signal distortion, harmonics, fundamental frequency deviation, ...).* | *2* |
| 13. *Decision making process, decision regions and borders, deterministic and probabilistic decision making methods.* | *2* |
| 14. *Adaptive control and protection systems, multicriterial systems, integrated measurement, control and protection systems* | *2* |
| 15. *Wide area measurements in power systems.* | *2* |

- Classes – the contents:
- Seminars – the contents:
- Laboratory – the contents:
  1. Elements of signal analogue processing path
  2. Design and analysis of digital filters, discrete Fourier transform
  3. Digital measurement of signal magnitude
  4. Algorithms for power and impedance components estimation
  5. Estimation of chosen criterion values
  6. Decision making methods and algorithms

The students use already available PC programs and write their own procedures in Matlab.Project – the contents:

- Basic literature:

[1] H. Ungrad, W. Winkler, A. Wiszniewski: “Protection techniques in electrical energy systems”, Marcel Dekker Inc. New York, Basel, Hong Kong, 1995.

[2] T. Krauss, L. Shurc, J. Little: Signal processing toolbox for use with Matlab, Users Guide.

[3] L.B. Jackson: Digital filters and signal processing, Kluwer Academic Publishers, Boston, 1986.

- Additional literature:
- Conditions of the course acceptance/credition:
  Lecture – passing the exam
  Laboratory – reports from all scheduled exercises

***** - depending on a system of studies