# STUDY COURSE DESCRIPTION FORM

| Name of the course | Code |
|---|---|
| **Three dimensional electromagnetic field calculation in electrical machines** | |
| Name of the doctoral school | Year /Semester |
| **Poznan University of Technology Doctoral School** | **….** |
| Specialty/Discipline | Type (obligatory, elective): |
| **Automation, electronic and electrical engineering** | **elective** |
| No. of hours | No. of credits |
| Lectures: **4** Classes: **-** Laboratories: **-** Seminars: **-** | **1** |

| **Cycle of study:** | **Form of study:** | **Assessment:** (written exam, presentation, etc.) |
|---|---|---|
| Third-cycle studies (Polish Qualifications Framework level eight) | Full-time | Written test |

**Responsible for the course/lecturer:**

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**Prerequisites in terms of knowledge, skills and social competencies:**

| | |
|---|---|
| 1 | **Knowledge:** Knowledge on the key developmental trends in electrical engineering software and elementary knowledge of partial differential equations and electrical machines |
| 2 | **Skills:** use the knowledge of elementary numerical methods and basic skills in computational research environments and computational techniques |
| 3 | **Social competencies:** acknowledge the importance of new computational methods and modern physics understanding in the development of technical sciences |

**Objectives of the course:**

Getting Knowledge of the modern field methods in the analysis and synthesis of electromagnetic machines and drives.

**Educational results (Study outcomes)**

**Knowledge:**

| | | |
|---|---|---|
| **P8S_WG** | Student knows key developmental trends of the modern field methods in the analysis and synthesis of the systems with electric and magnetic field | **SzD_W02** |
| **P8S_WG** | Student understands the methodology of 3D electromagnetic field calculation in systems of low frequency | **SzD_W03** |
| **P8S_WG** | Student can promote the new approaches in electromagnetic field calculation | **SzD_W04** |

**Skills:**

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|---|---|---|
| **P8S-UW** | Student can developed the method of electromagnetic fields calculation and can create new software for design of electrical machines and drives | **SzD-U01** |

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|---|---|---|
| **P8S-UW** | Student can critically analyze the results of numerical method application in the design of electromagnetic systems and coupled filed problems | **SzD-U02** |
| **P8S-UK** | Student can share results of electromagnetic field calculation in a popular form | **SzD-U05** |
| **P8S-UO** | Student can plan research project with the application of new 3D methods of electromagnetic field calculation | **SzD-U09** |
| **Social competencies:** | | |
| **P8S-KK** | Student is ready to critically assess the achievements in the electromagnetic field calculation, including the achievements proposed by commercial software | **SzD-K01** |
| **P8S-KO** | Student can think and act in an entrepreneurial manner as a designer of modern electrical machines and drives | **SzD-K06** |
| **P8S-KR** | Student is ready to maintain the ethos of research in electromagnetism, including independent activity in the numerical methods of electric drive calculation and design | **SzD-K07** |

**Compulsory literature:**

1. Silvester Peter P., Ferrari Ronald L., *Finite elements for electrical engineers*, Cambridge University Press; 3 edition, 1996
2. Demenko A., *Obwodowe modele układów z polem elektromagnetycznym*, Wyd. Pol. Poznańskiej, 2004,(in Polish)
3. Meunier G., *The finite element method for electromagnetic modeling*, John Wiley & Sons, 2008
4. Bastos João Pedro A., Sadowski Nelson, *Magnetic materials and 3D finite element modeling*, CRC Press, 2013
5. Dolezel I., Karban P., Solin P., *Integral methods in low-frequency electromagnetics*, Wiley and Son, New Jersey, 2009

**Additional literature:**

1. Bianchi Nicola, *Electrical machine analysis using finite elements*, CRC Press (2005)
2. Salon Sheppard J., *Finite elements analysis of electrical machines*, SPRINGER (SIE), (2006)
3. Hameyer Kay, Belmans Ronnie, *Numerical modelling and design of electrical machines and devices*, WIT Press (1999)
4. Demenko A., *Symulacja dynamicznych stanów pracy maszyn elektrycznych w ujęciu polowym*, Wyd. Pol. Poznańskiej, 1997 (in Polish)
5. Demenko A., J, Sykulski J., *Network equivalents of nodal and edge elements in electromagnetics*, *IEEE Trans. on Magnetics*, Vol. 38, March, 2002,
6. Demenko A., *Representation of windings in the 3d finite element description of electromagnetic converter*s, *IEE Proceedings Science, Measurement and Technology*, Vol. 149, September 2002,
7. Demenko A., Wojciechowski R., Sykulski J., *2-D versus 3-D electromagnetic field modeling in electromechanical energy converters*, IEEE Trans. on Magnetics, Vol. 50, No.2, 2014

## COURSE DESCRIPTION

| | General issues | Specific issues | No. of hours |
|---|---|---|---|
| **1** | Description of electromagnetic field | • Differential equations, integral equations, constitutive equations, circuit representation of electromagnetic field equations, scalar and vector potentials | **1** |
| **2** | New approach of finite element method for magnetic and electric field | • Nodal, elements, edge elements, facet elements and volume elements, circuit representation of finite element equations, edge and facet magnetic and electric network, coupled network in the analysis of electromagnetic field, time step method, method of complex variables | **1** |

| | | | |
|---|---|---|---|
| **3** | Description of winding in finite element space | • Multiply connected conductors in the edge element and facet element space, potential $T_0$ in the coupled field-circuit models | **0.5** |
| **4** | Movement simulation and electromagnetic torque and force calculation in the finite element method | • Methods of movement simulation: (a) fixed grid method, (b) moving grid method. Virtual work principle for discrete models, network representation of stress tensor method and Lorentz formula | **0.5** |
| **5** | Transformation of 3D models into the 2D network | • Symmetry of magnetic and electric field in electrical machines and actuators. Plane and axisymmetric magnetic field, Equivalence of nodal and edge element finite element equations for 3D and 2D field | **0.5** |
| **6** | Software for electromagnetic field calculation | • Preprocessor, solver, post processor and the components of these three groups of software. Formulation of input date. Mapping of electric and magnetic field. | **0.5** |

**Assessment methods of educational results**

Lectures:
- assessment of knowledge and skills by the completion of a written test (solving problem),
- continuous evaluation for the course (rewarding activity and quality of the expression).

Extra points for the activity in the classroom, and in particular for:
- discussion and proposition of additional aspects of the subjects,
- effectiveness of the application of the knowledge gained during solving the given problem.

**STUDENT'S WORKLOAD**

| Activity | Hours |
|---|---|
| Participation in lectures, classes, seminars and laboratories | 4 |
| Contact hours with lecturers (including consultations) | 5 |
| Self-study | 4 |
| Exam | 1 |
| TOTAL | **14** |
| TOTAL NUMBER OF ECTS POINTS FOR THE COURSE | 1 |