**AGU Graduate School of Engineering and Science Electrical and Computer Engineering Program**

**COURSE RECORD**

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|---|---|
| Code | **ECE558** |
| Name | **Dynamics and Control of AC Drives** |
| Hour per week | 3 + 0 (Theory + Practice) |
| Credit | 3 |
| ECTS | 7,5 |
| Level/Year | Graduate |
| Semester | Spring |
| Type | Elective |
| Location | TBD |
| Prerequisites | EE 308 Electric Machines and Drives, ECE*** Introduction to Electric Drive Systems |
| Special Conditions | N/A |
| Coordinator(s) | Dr. Burak Tekgün |
| Webpage | N/A |
| Content | 1. AC machine model development,<br>2. Complex variable analysis of induction and synchronous machines,<br>3. Digital simulation of electric machines and drives,<br>4. DQ models for power converters and current regulation,<br>5. Field oriented (vector) control of AC machines,<br>6. Direct torque control,<br>7. Small signal dynamic analysis of AC machines. |
| Objectives | 1. To provide the methods used for modeling the AC machines via winding functions.<br>2. To provide the knowledge for modeling AC machines using complex vectors and dq transformations.<br>3. To introduce the techniques used for power converter modeling.<br>4. To provide the principles of field oriented (vector) control, types of field oriented control and their implementation.<br>5. To introduce the flux weakening operation of vector controlled AC machines<br>6. To introduce direct torque control of AC machines.<br>7. To develop and analyze the small signal model of AC machines. |
| Learning Outcomes | LO1 Understand coupled circuit modeling of AC machines<br>LO2 Understand the complex variable analysis of AC machines<br>LO3 Understand the principle of direct and quadrature axis representation, stator, rotor reference frames<br>LO4 Learn how to simulate AC electric machines and drives<br>LO5 Understand the principles of current regulation.<br>LO6 Understand the principles of field oriented control<br>LO7 Understand the current and voltage limits of AC drives and flux (or field) weakening operation.<br>LO8 Understand the direct torque control technique<br>LO9 Understand the development of the small signal model of AC machines. |
| Requirements | Matlab / Simulink or similar simulation software. |
| Reading List | Textbook: "Vector Control and Dynamics of AC Drives," D. W. Novotny, T. A. Lipo, 1996, Oxford – Clarendon Press.<br>Additional Material:<br>1. "Analysis of Electric Machines and Drive Systems," P. C. Krause, O. Wasynczuk, S. D. Sudhoff, 2002, IEEE Press.<br>2. "Vector Control of Three-Phase AC Machines," N. P. Quang, J. A. Dittrich, 2008, Springer. |
| Ethical Rules and Course Policy | Students are not allowed to collaborate on homework assignments, exams, and project reports. Project reports will be written and graded individually. |

## LEARNING ACTIVITIES

| Activities | Number | Weight (%) |
|---|---|---|
| Lecture | 14 | 90% |
| Presentations | 2 | 10% |
| | | |
| | Total | 100 |

## ASSESSMENT

| Evaluation Criteria | Weight (%) |
|---|---|
| Homework Assignments | 30% |
| Project Assignments & Presentations | 35% |
| Final Exam/Submission | 35% |
| Total | 100% |

For a detailed description of grading policy and scale, please refer to the website https://goo.gl/HbPM2y section 28.

## COURSE LOAD

| Activity | Duration (hour) | Quantity | Work Load (hour) |
|---|---|---|---|
| In class activities | 3 | 16 | 48 |
| Homework Assignments | 5 | 11 | 55 |
| Group work | 3 | 12 | 36 |
| Research (web, library) | 5 | 16 | 80 |
| Required Readings | 5 | 16 | 80 |
| Pre-work for Presentation | 8 | 2 | 16 |
| | | | |
| | | **General Sum** | **315** |

**ECTS: 7,5** (Work Load/25-30)

## CONTRIBUTION TO PROGRAMME OUTCOMES*

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 | PO13 | PO14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LO1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LO2 | 5 | 5 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LO3 | 0 | 5 | 5 | 5 | 5 | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LO4 | 0 | 0 | 0 | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 3 | 0 | 0 | 0 |
| LO5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 |
| LO6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 0 |
| LO7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| LO8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| LO9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |

* Contribution Level: 0: None, 1: Very Low, 2: Low, 3: Medium, 4: High, 5: Very High

## WEEKLY SCHEDULE

| W | Topic | Outcomes |
|---|---|---|
| 1 | Coupled circuit analysis of AC machines, calculation of inductances and winding functions. | LO1, LO2 |
| 2 | Introduction to electrical radian notation, three phase idealized machine model, vector notation, voltage equations for 3 phase sinusoidal machine | LO2, LO3 |
| 3 | Voltage equations referred to the stator and rotor side ant their graphical interpretations. Two phase model of 3 phase sinusoidal machine. | LO3 |
| 4 | Quadrature and direct axis definition, transformations and inverse transformations, matrix notations, rotation transformation, machine equations in arbitrary reference frame, power equations for complex vectors. | LO3, LO4 |
| 5 | Electromechanical energy conversion, torque expressions, mechanical system equations, salient pole (wound field) synchronous machine. | LO3, LO4 |

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| 6 | Steady state solutions using complex instantaneous variables, steady state torque equations. | LO3, LO4 |
| 7 | Constant speed transients, forced and natural solutions, current source and voltage source excitations. | LO2, LO4 |
| 8 | Trapped flux equivalent circuit, transient analysis of AC machines in state variable form | LO4 |
| 9 | Per unit system, magnetic saturation and introduction to system simulation, dq converter modeling (VSI) | LO4 |
| 10 | Inverter modeling (CSI), inverter – machine (VSI) model, inverter – machine (CSI) model, current regulation on AC machines, PWM-VSI current regulations, hysteresis current regulation. | LO4, LO5 |
| 11 | Ramp comparison current regulator, stationary frame dq current regulator, synchronous frame dq current regulator, space vector modulation, torque control in AC machines, steady state field oriented control (FOC) equations, indirect and direct FOC. | LO4, LO5, LO6 |
| 12 | Torque production and voltage equations in FOC induction machines. Differences between the FOC in IM and SM (wound field), detuning effects if indirect FOC and its dynamics | LO6 |
| 13 | FOC using air gap flux, field weakening in IM for FOC, Interactions of current and voltage limits, synchronous reluctance machines, Interior permanent magnet (IPM) machines constant power operation of IPM machines. | LO6, LO7 |
| 14 | Direct torque control and its implementation, small signal analysis of induction machines. | LO8, LO9 |