EE 599d: Advanced wind energy conversion systems (AWECS)

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| **Lecture Schedule** | | Tues: 06:00 PM to 07:30PM  Frid: 07:30PM to 09:00PM | **Course Type,**  **Semester** | Core for Power/Control/ Electronics Fall 2018 | | |
| **Credit Hours** | | Three | **Pre-requisites** | Power Electronics,  Control of Electrical Machine, Electric Circuits(UG). | | |
| **Instructor** | | Dr. S. A. Kamran Shah Jafri | **Contact** | [kame7970@yahoo.com](mailto:kame7970@yahoo.com)  Mobile:03363865066 | | |
| **Course Description** | | The course covers wind energy potential in Pakistan, wind turbine technology: classification, components, aerodynamics & modeling. Fundamentals of Wind Energy Conversion System Control, fixed, single, two-speed, variable Speed Induction Generator based WECS. Designing reactive power compensation scheme for fixed-speed WECS, Direct Field Oriented Control for SCIG-WECS, dynamic & steady-state analysis of Direct FOC-WECS, Indirect Field Oriented Control, Principle of Direct Torque Control. Control of Synchronous Generators: Zero *d*-axis Current (ZDC) Control, Maximum Torque Per Ampere (MTPA) Control , Unity Power Factor (UPF) Control, Comparison of ZDC, MTPA and UPF Controls ,SG Wind Energy System with Back-to-back VSCNon-salient SG WECS with ZDC and Optimal Torque Control. Associated problems, simulation models & case studies. | | | | |
| **Measurable Learning Outcomes** | **CLOs** | **Description** | | | **Domain, Level** | **PLOs, Level** |
|  | CLO1 | Demonstrate understanding of the wind energy potential in Pakistan, basic concepts of wind turbine technology, classifications, fixed-speed and variable-speed wind energy systems, wind turbine components, & aerodynamics. | | | Cognitive,  3 | PLO1,  Medium |
|  | CLO2 | Assess fundamentals of Wind Energy Conversion System Control, Fixed, single & two-speed WECS, variable Speed Induction Generator WECS: (i) Wound Rotor Induction Generator with External Rotor Resistance, (ii) Doubly Fed Induction Generator WECS with Reduced-capacity Power Converter & ,(iii)SCIG Wind Energy System with Full-capacity Power Converters. | | | Cognitive  5 | PLO2,  High |
|  | CLO3 | Demonstrate understanding of the Direct Field Oriented Control, Direct FOC for SCIG Wind Energy Systems, Dynamic & Steady-state Analysis of Direct FOC WECS, Indirect Field Oriented Control, Principles of Operation of Indirect FOC, Steady-state Analysis of Indirect FOC SCIG Wind Energy System, Direct Torque Control, Principle of Direct Torque Control, Switching Logic, Stator Flux and Torque Calculator, Transient Analysis of SCIG WECS with DTC. | | | Cognitive,  3 | PLO3,  Medium |
|  | CLO4 | Discuss System Configuration, Control of Synchronous Generators, Zero d-axis Current (ZDC) Control, Maximum Torque Per Ampere (MTPA) Control, Unity Power Factor (UPF) Control Comparison of ZDC, MTPA and UPF Controls, SG Wind Energy System with Back-to-back VSC Non-salient SG WECS with ZDC and Optimal Torque Control, Transient and Steady-state | | | Cognitive,  2 | PLO1,  Low |
| **Textbook** | | [Power Conversion and Control of Wind Energy Systems by B. Wu, Y. Lang, N. Zargari, and S. Kouro Wiley-IEEE Press,2011, ISBN: 978-0-470-59365-3](file:///C:\Users\SyedAliKamranShahJaf\Desktop\UET\books%20on%20wind%20energy\Dr.bin%20wu%20book.pdf) | | | | |
| **Reference Texts** | | 1. [Thomas Ackermann, Wind Power in Power Systems, John Wiley & Sons Ltd, 2012, ISBN: 978-0-470-97416-2.](C:\\Users\\SyedAliKamranShahJaf\\books on wind energy\\Wind Power in Power.pdf) 2. Dynamic Simulations of Electric Machinery: Using MATLAB/SIMULINK, by Dr. CHEE-MUN ONG Prentice Hall,1997, ISBN-13: 978-0137237852.  Power Electronics for Renewable Energy Systems, Transportation and Industrial Applications by Haitham Abu‐Rub, Mariusz Malinowski & Kamal Al‐Haddad, John Wiley & Sons, Ltd,2014 ISBN:9781118634035.  1. Modeling and Analysis of Doubly Fed Induction Generator Wind Energy Systems by Lingling Fan and Zhixin Miao, Academic Press, 2015, ISBN: 9780128029695. | | | | |
| **Grading Policy vis-à-vis CLO Mapping** | | * Quizzes (≥ 4) + Assignments 30% CLO1-CLO4 * Midterm 30% CLO1 * Final 40% CLO2 & CLO4 | | | | |

**Lecture Plan**

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| **Wk.** | Topics | **Readings & CLOs** |
| **1.5\*** | **Introduction**  Wind energy potential in Pakistan, alternative/renewable resources: wind power, wind resource studies, wind turbine technology, wind energy conversion, fixed-speed and variable-speed wind energy systems. wind turbine components, wind turbine aerodynamics, turbine power characteristics, turbine modeling, passive and active stall controls, pitch control, tip speed ratio, maximum power point tracking schemes. | **Ch. 1/2**  **CLO1** |
| **1.5\*** | **Wind Energy System Configurations**  Fundamentals of Wind Energy Conversion System Control, Fixed, single & 2-speed WECS, variable Speed Induction Generator WECS: (i)Wound Rotor Induction Generator with External Rotor Resistance, (ii)Doubly Fed Induction Generator WECS with Reduced-capacity Power Converter & ,(iii)SCIG Wind Energy System with Full-capacity Power Converters, variable-speed Synchronous Generator WECS:(i) Configuration with Full-capacity back-to-back Power Converters, (ii) configuration with Diode Rectifier & c/dc Converters, (iii) configurations with Distributed Converters for multi-winding Generators. | **Ch. 5**  **CLO1** |
| ***Quiz-1 will be taken in the 4th week*** | | |
| **4\*** | **Fixed-Speed Induction Generator WECS**  Configuration of Fixed-Speed Wind Energy Systems, Operation Principle, Fixed-speed Operation of SCIG Two -speed Operation of Fixed-Speed WECS , Grid Connection with Soft Starter, Reactive Power Compensation Reference frame transformation, induction generators (IG), IG dynamic and steady state models, synchronous generators (SG), SG dynamic and steady state models, transient and steady state analysis of wind generators. Associated problems, Further analysis is carried out by computer simulations & case studies. | **Ch.6**  **CLO2** |
| ***Mid-term will be conducted on 8th week*** | | |
| **4\*** | **Variable-Speed WECS with Squirrel Cage Induction Generators**    Direct Field Oriented Control, Direct FOC for SCIG Wind Energy Systems, Dynamic & Steady-state Analysis of Direct FOC WECS, Indirect Field Oriented Control, Principles of Operation of Indirect FOC, Steady-state Analysis of Indirect FOC SCIG Wind Energy System, Direct Torque Control, Principle of Direct Torque Control ,Switching Logic, Stator Flux and Torque Calculator ,Transient Analysis of SCIG WECS with DTC, Steady-state Analysis of SCIG WECS with DTC, Control of Current Source Converter Interfaced WECS ,Control of CSC WECS with Variable α and Fixed m ,Steady-state Analysis of CSC WECS Associated problems, simulation models & case studies,Further analysis is carried out by computer simulations & case studies. In this Chapter, 3 control schemes are presented & analyzed in detail. | **Ch. 7**  **CLO3** |
| ***Quiz-2(at scheduled time)*** | | |
| **4\*** | **Variable-Speed WECS with Synchronous Generators**  System Configuration, Control of Synchronous Generators, Zero *d*-axis Current (ZDC) Control, Maximum Torque Per Ampere (MTPA) Control ,Unity Power Factor (UPF) Control Comparison of ZDC, MTPA and UPF Controls ,SG Wind Energy System with Back-to-back VSCNon-salient SG WECS with ZDC and Optimal Torque Control ,Transient and Steady-state Analysis of Non-salient SG WECS ,Salient-pole SG WECS with MTPA and Rotor Speed Feedback Controls ,Transient and Steady-state Analysis of Salient-pole SG WECS, Grid-side MPPT Control Scheme ,DC/DC Boost Converter Interfaced SG Wind Energy System ,Reactive Power Control of SG WECS ,Current Source Converter Based SG Wind Energy Systems ,CSC Wind Energy Systems with Firing Angle Control ,CSC Wind Energy System with Reactive Power Control, Associated problems, simulation models & case studies, Further analysis is carried out by computer simulations & case studies. In this Chapter, three control schemes are presented & analyzed in detail. | **Ch. 9**  **CLO4** |
| ***Quiz-3/4 (at scheduled time)*** | | |
| ***Final*** | | |

**\* -** Tentative