Department of Electrical Engineering
Energy and Power Systems

Introduction to
Electric Machines and Drives

Jae-Do Park, Ph.D.
Energy and Power Systems for Electrical Engineering (UC-Denver)
Degree Requirements Flow Chart

EE Foundation

- **ELEC 1201-1**
  - Introduction to Electrical Eng.
- **EE 3133-3**
  - Electromagnetic Fields
- **ELEC 2132/2142-3**
  - Circuit Analysis I & II
- **ELEC 3316-3**
  - Linear Systems Theory

Specialty Foundations

- **ELEC 3164-3**
  - Energy Conversion
- **ELEC 3724-1**
  - Energy Conversion Lab

Specialty

(Core Courses in Power Engineering)

- **ELEC 4164/5164-3**
  - Electric Drive Systems
- **ELEC 4174/5174-3**
  - Power Electronic Systems
- **ELEC 4184/5184-3**
  - Power Systems Analysis
- **ELEC 4808/5808-3**
  - Renewable Energy Systems
- **ELEC 4xxx-1**
  - Electric Drive Lab
- **ELEC 4xxx-1**
  - Power Electronic Lab
- **ELEC 4xxx-1**
  - Power Systems Lab
- **ELEC 4xxx-1**
  - Renewable Energy Lab

Graduate

- **ELEC 5xxx-3**
  - Advanced Electric Drive Systems
- **ELEC 5xxx-3**
  - Advanced Electric Machinery
- **ELEC 5xxx-3**
  - Practical Electric Drive Systems
- **ELEC 5821-3**
  - Advanced Power Electronic Systems
- **ELEC 5xxx-3**
  - Electric Power Quality
- **ELEC 5xxx-3**
  - Power Systems Dynamics and Protection
- **ELEC 5xxx-3**
  - Power System Operation and Control
- **ELEC 5xxx-3**
  - Substations Engineering Design
- **ELEC 5xxx-3**
  - Advanced Distribution Systems
- **ELEC 5813-3**
  - Energy Systems Planning

Legend

- Required
- Required lab
- Elective/Graduate
- Elective lab
- Graduate
Energy and Power Systems Engineering in Electrical Engineering (UC-Denver)

**Machines and Drives Course Flow Chart**

**EE Foundation**
- **EE 1201-1**  
  Introduction to Electrical Eng.
- **EE 2132/2142-3**  
  Circuit Analysis I & II
- **EE 3133-3**  
  Electromagnetic Fields
- **EE 3316-3**  
  Linear Systems Theory

**Machines/Drives Foundation**
- **EE 3164-3**  
  Energy Conversion
- **EE 3724-1**  
  Energy Conversion Lab

**Machines/Drives Specialty**
- **EE 4164-F3**  
  Electric Drive Systems
- **EE 4xxx-1**  
  Electric Drive Systems Lab

**Machines/Drives Advanced**
- **EE 5xxx-3**  
  Practical Electric Drive Systems
- **EE 5xxx-3**  
  Advanced Electric Drive Systems
- **EE 5xxx-3**  
  Advanced Electric Machinery

**Legend**
- Required
- Required lab
- Elective
- Elective lab
- Graduate
Electric Machines and Drives

• Area covers
  – Mechanical system for electric machines
  – Power electronics converters
  – Magnetic circuits
  – Electric machine modeling
  – Control algorithms
  – Drive system design
  – Commercial drive operation
Jae-Do Park, Ph.D.

- Ph.D., Pennsylvania State University, 2007
- Expertise includes machine modeling and drive system design
- 12 years of industry experience on induction and synchronous reluctance machine drive
- Published 6 IEEE journal and conference papers, Invented 4 patents
- Renewable Energy Club advisor
- Member of ECRF at UC Denver
Electric Machines

- Electromechanical system
  - Electrical side
    - Voltage \( v \), current \( I \), flux-linkage \( \lambda \)
    - Electrical Power
  - Mechanical side
    - Force \( f \), linear displacement \( x \)
    - Torque \( \tau \), rotational displacement angle \( \theta \)
    - Mechanical Power

\[ P_{\text{elec}} \rightarrow P_{\text{mech}} \]

Motoring mode
Generating mode
Electric Machines

• Classification
  – AC & DC machines
  – Rotary & linear machines
  – Synchronous & asynchronous machines
  – Brush & brushless machines
  – More classification can be possible
Electric Machines

• Construction

  – Stationary “Stator” and rotating “Rotor”
  – Built with high permeability material
    • What’s the advantage of higher permeability?
5W1H: Electric Machine Drives

• What
  – A control system for an electric machine
    • ASD: Adjustable Speed Drive
    • VFD: Variable Frequency Drive
    • VVVF: Variable Voltage Variable Frequency
  – To control
    • Position, speed, torque, tension
    • Voltage, current, power
General Drives

General purpose inverter systems
LG Industrial Systems
Special Drives

Gearless Elevator System
LG-Otis

Flywheel Energy Storage System
Pentadyne Power
5W1H: Electric Machine Drives

• What: Fan/Pump/Blower
5W1H: Electric Machine Drives

- What – Elevator
5W1H: Electric Machine Drives

• What – Traction
5W1H: Electric Machine Drives

- What - Winder
5W1H: Electric Machine Drives

• What – Windmill

• Mechanical to Electrical Energy Conversion
5W1H: Electric Machine Drives

- What – Energy storage
5W1H: Electric Machine Drives

• Where
  – Industrial
  – Commercial
  – Almost everywhere
    • From a watch to a train

• When
  – You want to control
    • speed, torque, power, voltage, current, etc
5W1H: Electric Machine Drives

• Why
  – Better performance, efficiency
  – Cost reduction, less maintenance
  – Low noise
  – New applications

• Who
  – Design engineers
  – Application engineers
  – Manufacturing/process engineers
5W1H: Electric Machine Drives

• How
  – Power electronics converters
    • Control voltage & frequency
    • Using various power semiconductor devices
  – Mathematical modeling of electrical machines
  – Complex controllers using DSPs
    • Microprocessor/Microcontrollers
    • MMI (Man-Machine Interface)
    • Communication with various control devices
5W1H: Electric Machine Drives

- How – Power Electronics Converters
5W1H: Electric Machine Drives

• How – Power Electronics Converters

Rotating Magnetic Field

Induction Machine
5W1H: Electric Machine Drives

• How – Controller using DSPs

TI TMS320C6711 DSK board

IO expansion board

Controller using Motorola DSP56F803
5W1H: Electric Machine Drives

- How – MMIs
Practical Problems

• Elevator
Practical Problems

• Hybrid Car
  – Gas engine has maximum efficiency at 70% power. The machines in the hybrid car can operate as generators. The battery pack could be charged when:
    1) Going downhill (Y/N)
    2) Going uphill (Y/N)
    3) Breaking (Y/N)
    4) Accelerating (Y/N)

* Toyota Prius
Practical Problems

• Motions
  – Which one is a passenger train and which one is a cargo train?
Questions?