Electric Energy Systems Curriculum

With Emphasis on
- Renewables
- Smart Delivery
- Efficient End-Use

ONR-NSF Workshop
Minneapolis, MN June 7-12, 2010

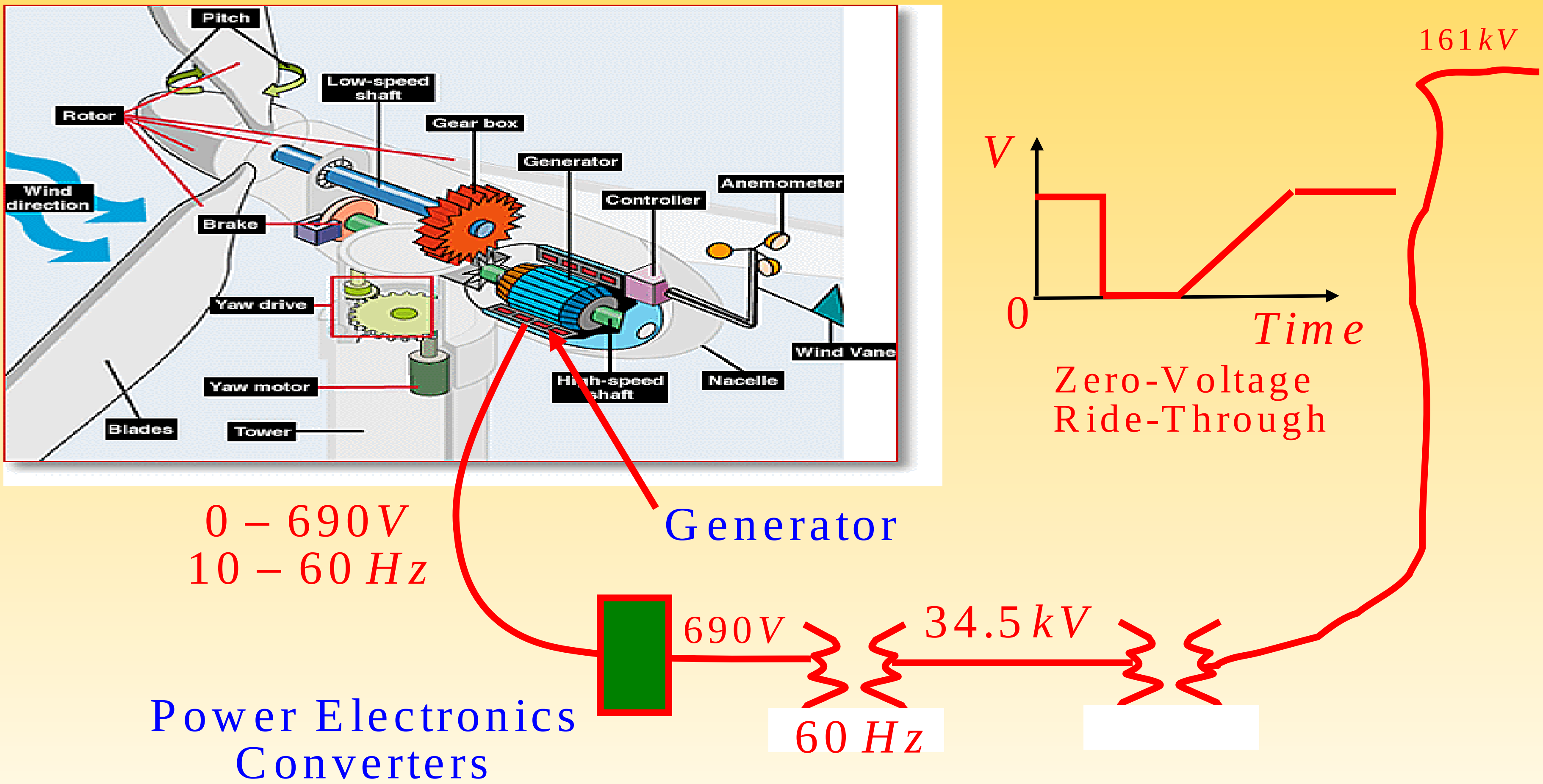
Wind Energy Essentials
College of Science & Engineering, UMN
(EE 5940 - Fall 2010)

1. Introduction (Fotis Sotiropoulos - CE, Ned Mohan - ECE)
2. New Challenges in a High Penetration of Wind Power (Ed Muljadi, Senior Engineer, National Wind Technology Center, NREL)
3. Gears/Transmission (Kim Stelson - ME)
4. Blade Aerodynamics and Acoustics (Fotis Sotiropoulos, Roger Arndt - CE)
5. Foundation Design (Chris Kopchynski, Jennifer Entwistle, Barr Engineering)
6. Controls (Mihailo Jovanovic - ECE, Gary Balas - AEM)
7. Electric Generation and Power Electronics (Ned Mohan - ECE)
8. Materials and Structural Reliability (Sue Mantell - ME, Henryk Stolarski - CE)
9. Wind Assessment and Wind Forecasting (Mark Ahlstrom, CEO, WindLogics Inc.)
10. Grid Integration (Matt Schuerger, Energy Systems Consulting Services)
11. Wind Farm Development, Socio-economic Aspects (Jack Levi – Co-Founder and Co-Chairman, National Wind LCC.)
12. Environmental Considerations – Radar Interference (Mos Kaveh – ECE, others TBD)

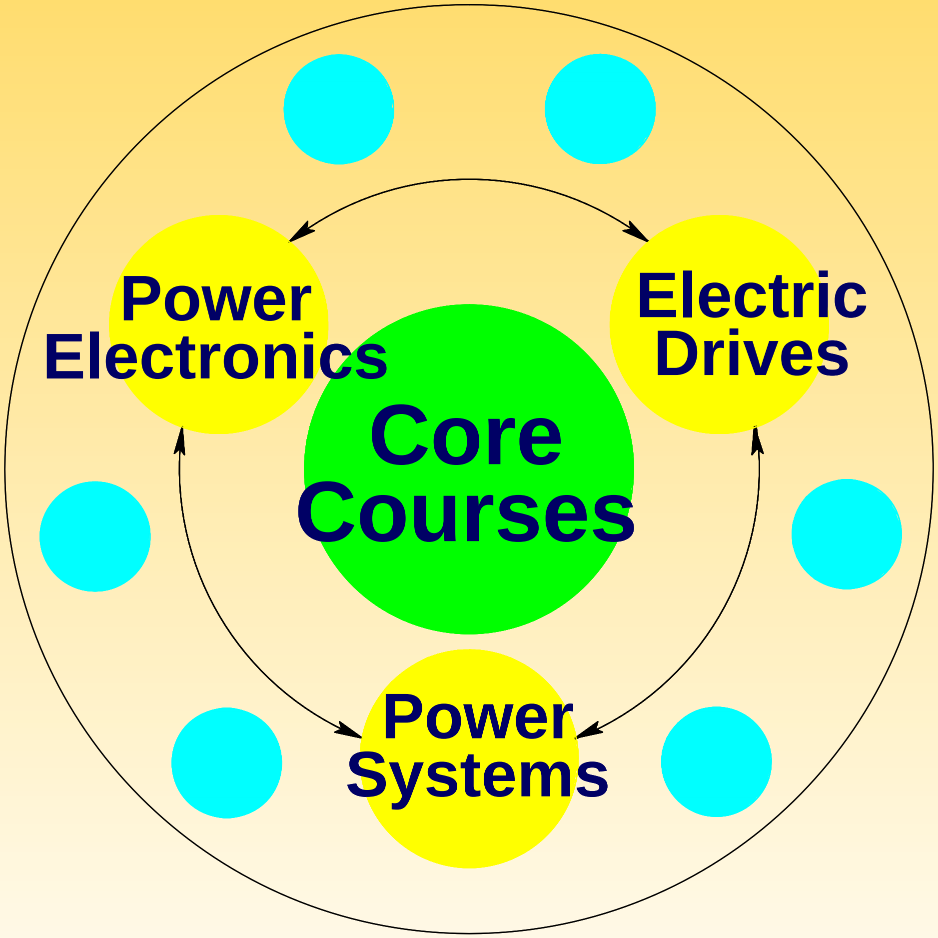
Regular Registration with CEUs:	**$225**
Registration without CEUs:	**$175**
Faculty Registration:	**$150**

UMN Curriculum

Wind Generation: Example of an Integrated System



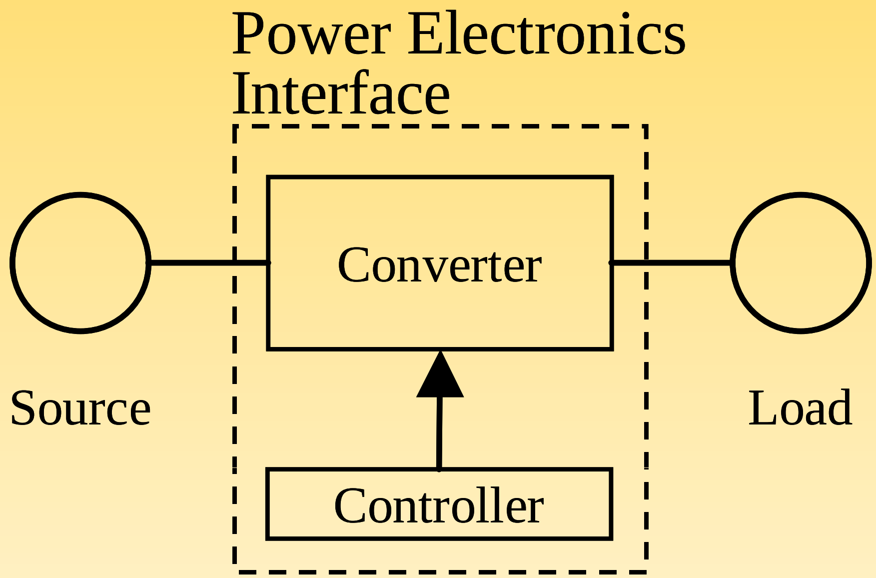
Our Integrated Curriculum – Only 3 Courses



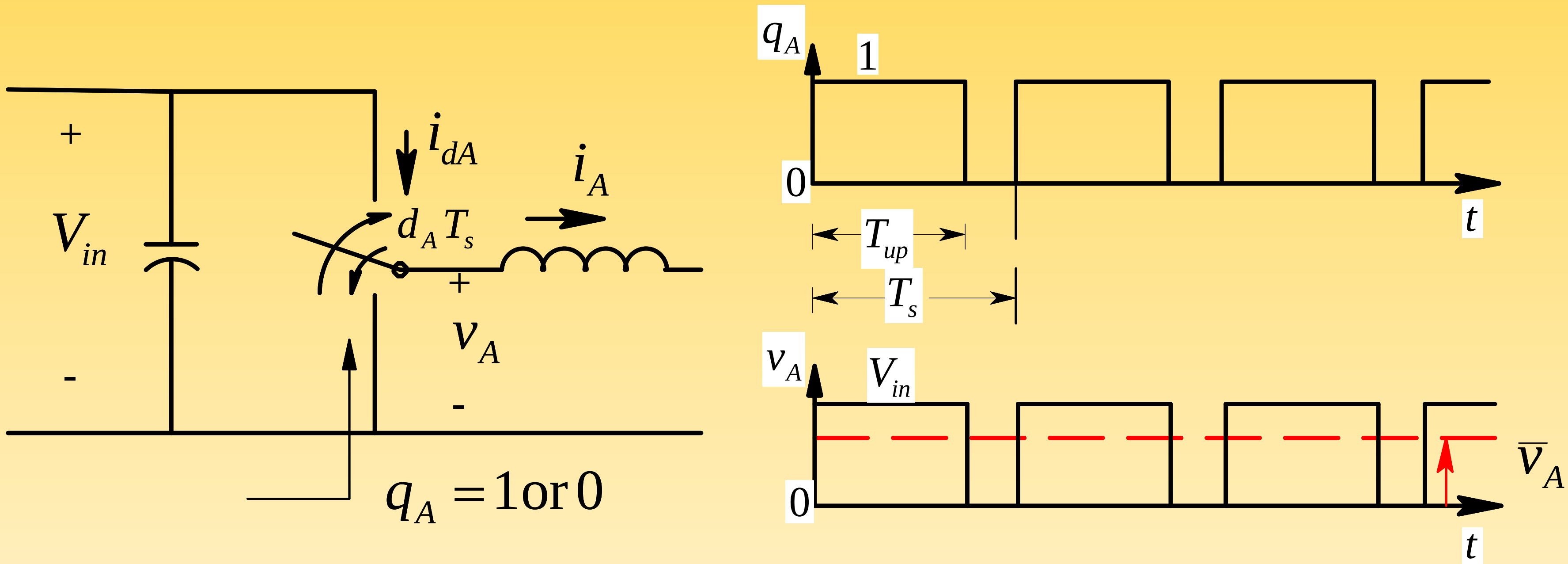
Complementary Courses:
- Analog/Digital Control
- DSPs, FPGAs
- Programming Languages
- Heat Transfer
- Thermo

Students are Broadly Trained; They can work in any field of EE.

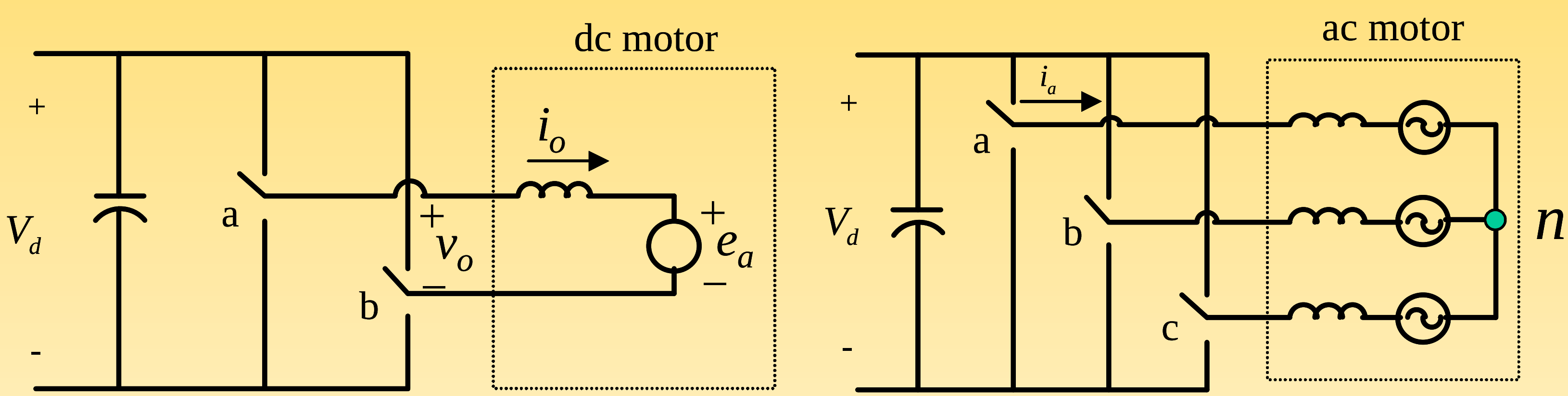
First Course in
Power Electronics



A Switching Power-Pole as a Building-Block:



Converters for DC and AC Motor Drives:

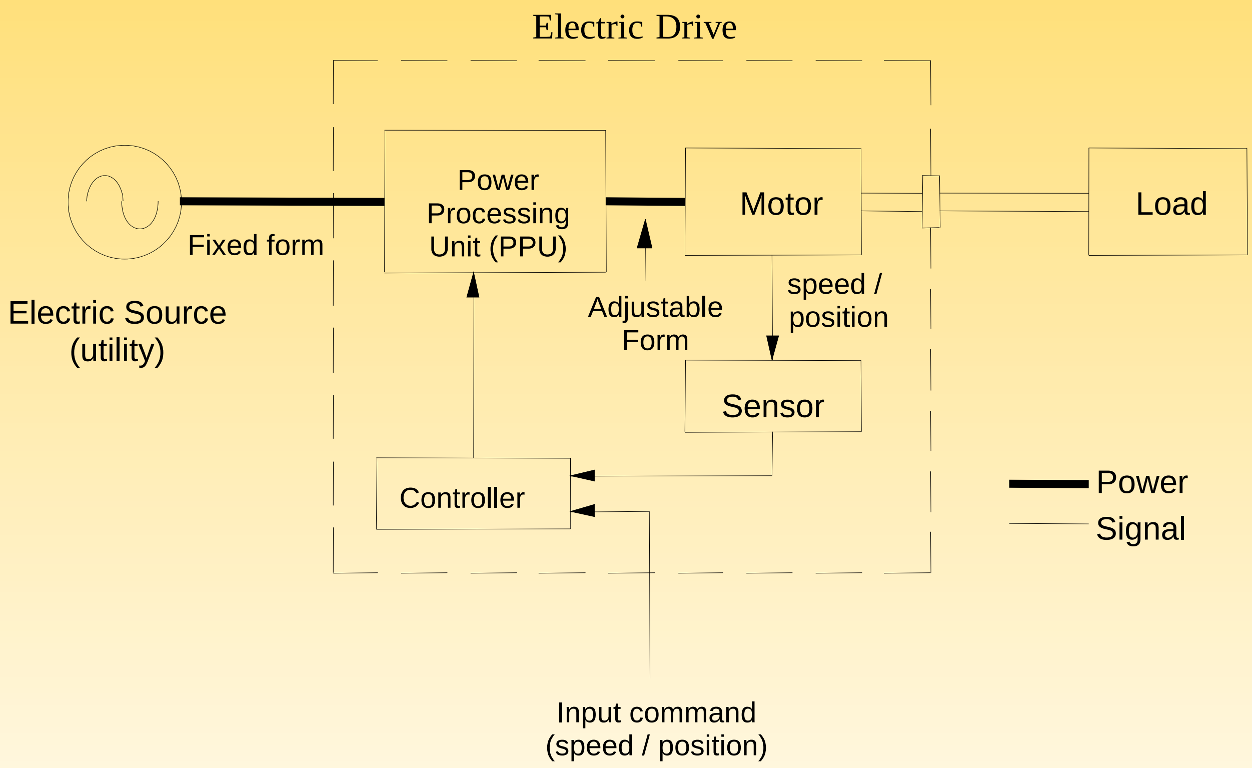


(*a*) (*b*)

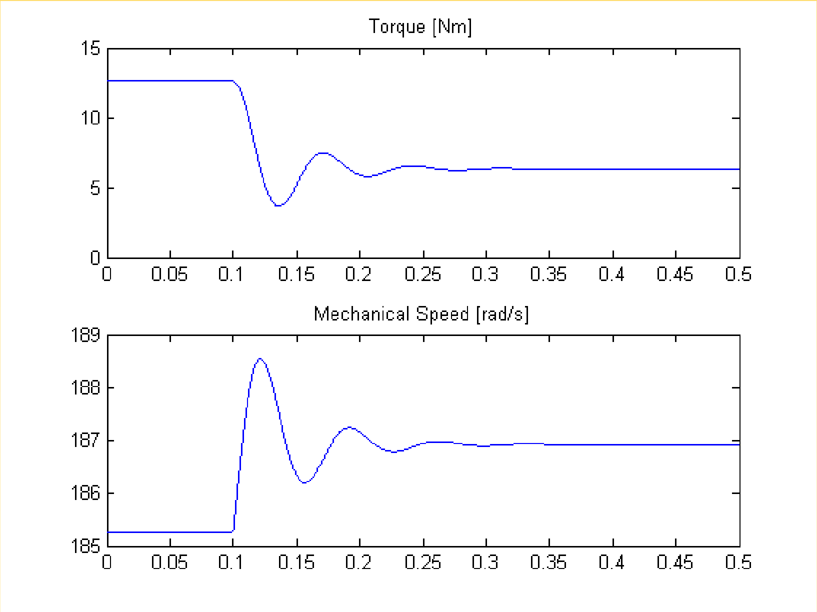
Topics Covered in this Course:

- Switch-Mode Converters
  - Buck, Boost, Buck-Boost
  - Flyback, Forward, Full-Bridge
  - DC and AC Motor Drives
  - Power-Factor-Correction Circuits
- Feedback Control
- Thyristor Converters

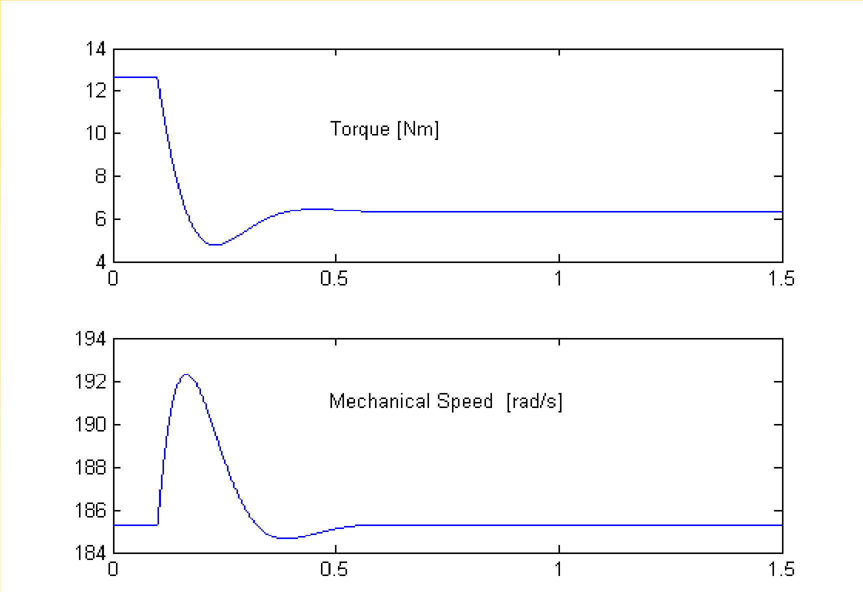
First Course on
Electric Drives



Uncontrolled Induction Motor Drive

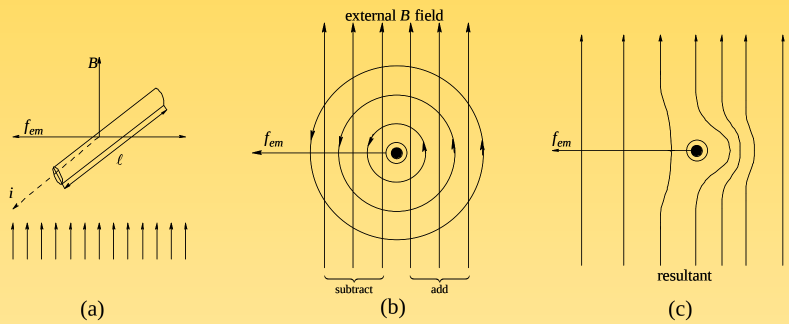


Vector Controlled Induction Motor Drive

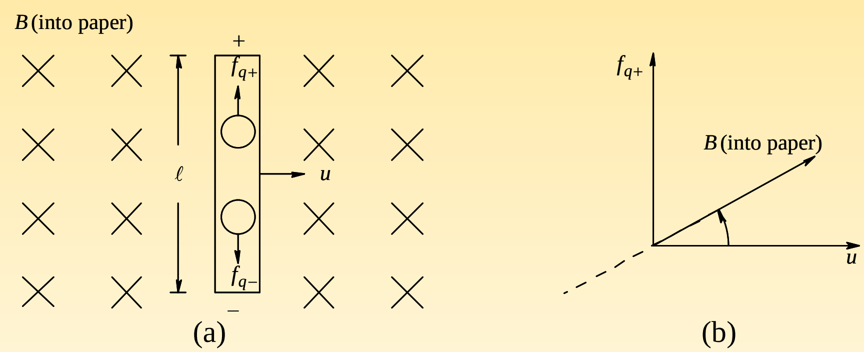


Physics Based:

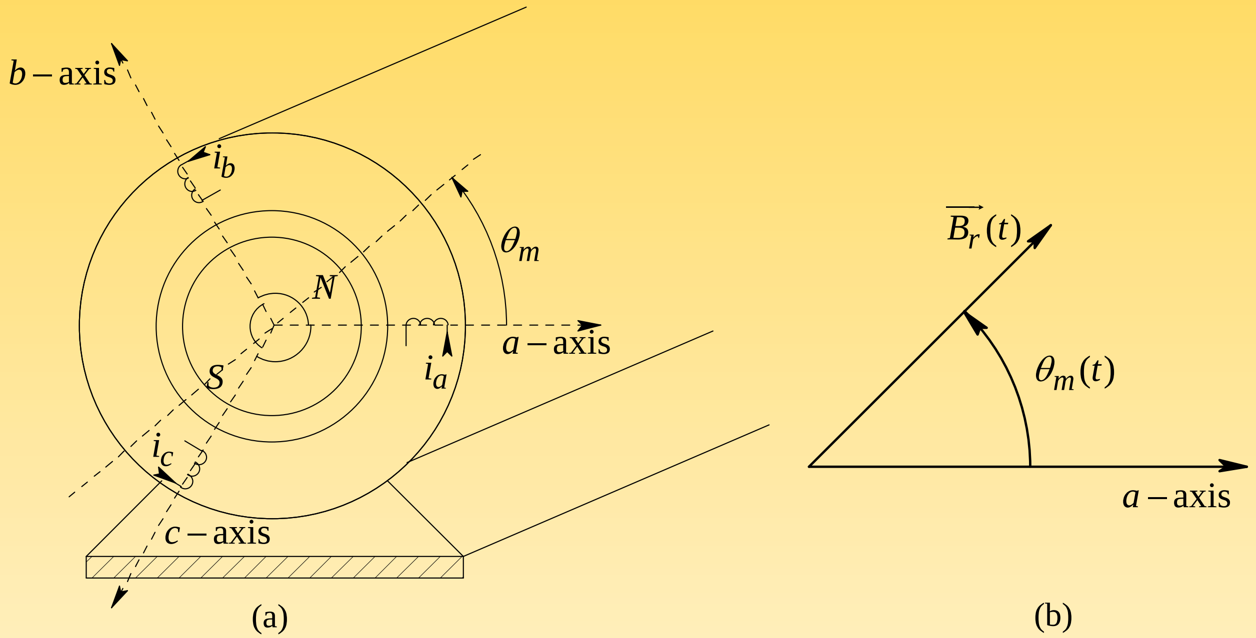
$$f_{em} = B\,i\,\ell$$



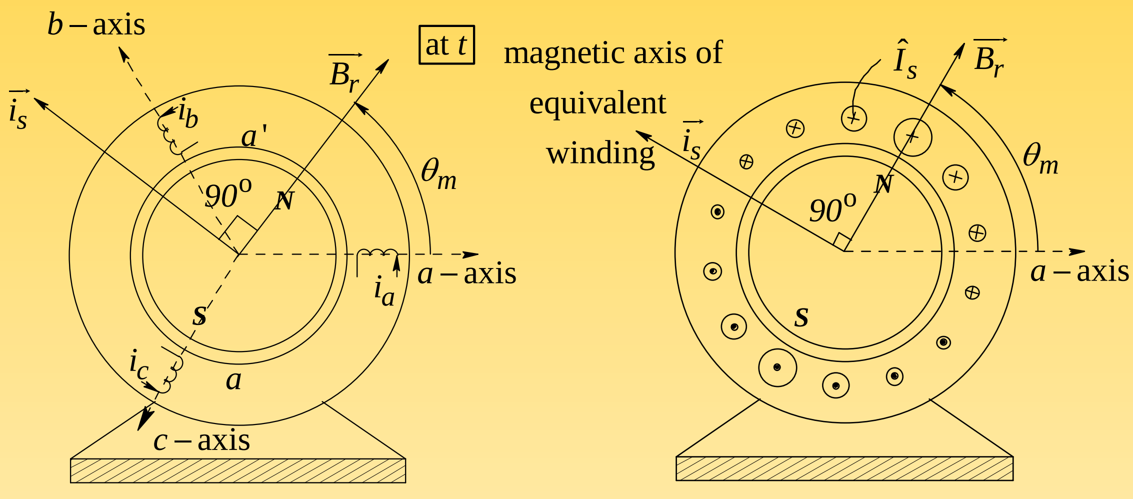
$$e = B\,\ell\,u$$



Use of Space Vectors:



Physics-based Analysis:



(a) (b)

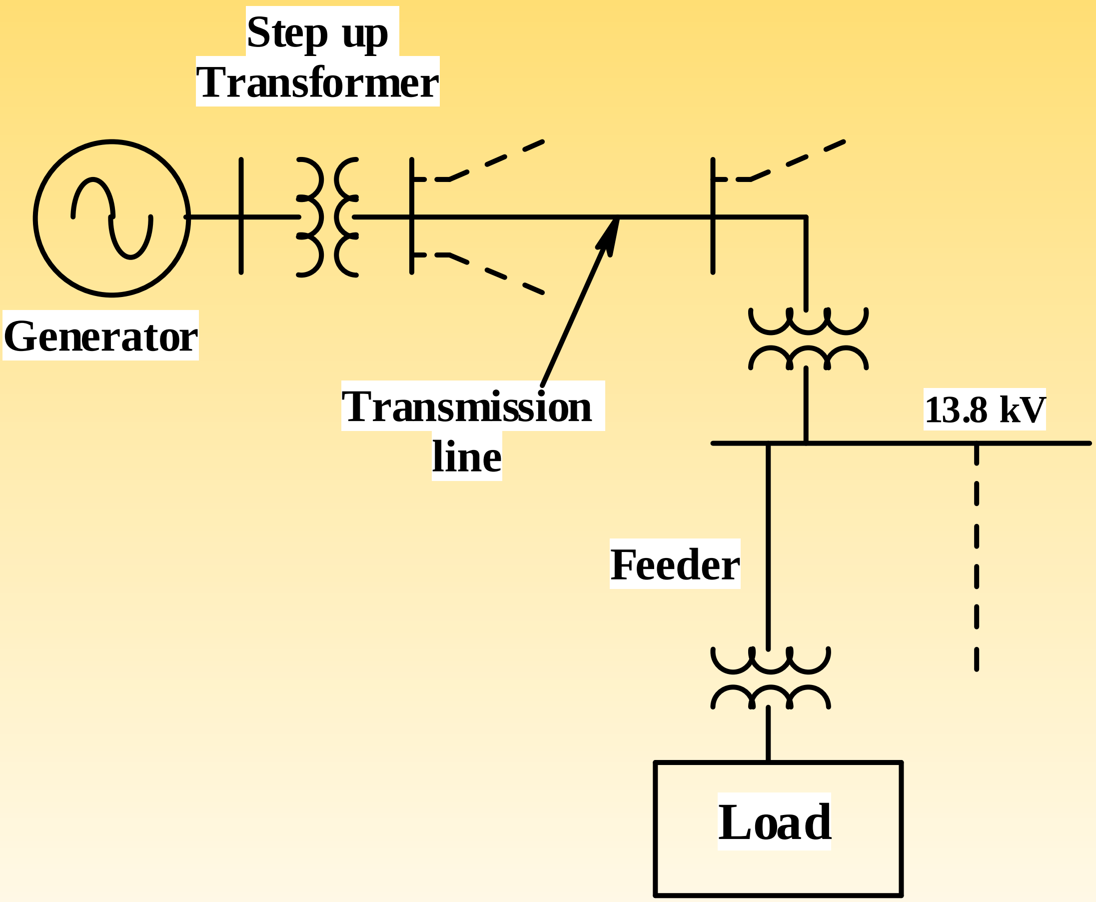
$$dT_{em}(\xi) = r \underbrace{\hat{B}_r \cos\xi}_{\text{flux density at } \xi} \cdot \underbrace{\ell}_{cond.\ length} \cdot \hat{I}_s \cdot \underbrace{\frac{N_s}{2}\cos\xi \cdot d\xi}_{no.\ of\ cond.\ in\ d\xi}$$

$$T_{em} = 2 \times \int_{\xi=-\pi/2}^{\xi=\pi/2} dT_{em}(\xi) = 2\frac{N_s}{2} r\ell\hat{B}_r\hat{I}_s \int_{-\pi/2}^{\pi/2} \cos^2\xi \cdot d\xi = (\pi\frac{N_s}{2} r\ell\hat{B}_r)\hat{I}_s$$

Topics:

- Designing for the Mechanical Load
- DC Motor Drives
- Permanent Magnet AC Drives
- Induction Motor Drives: Steady State and V/f Control
- Stepper and Switched-Reluctance Drives
- Feedback Control
- Power Quality Considerations

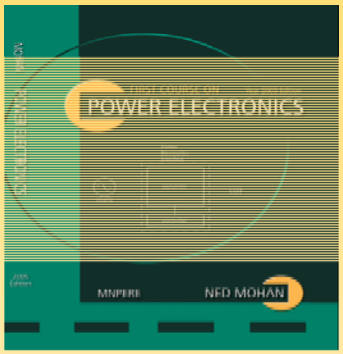
First Course on Power Systems



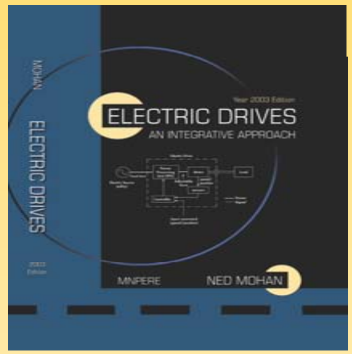
- Balanced Coverage of Topics
  - Changing Landscape and Resources
  - Apparatus in Generation & Delivery of Power
  - Analysis and Operation
  - Fault Protection

Resources:

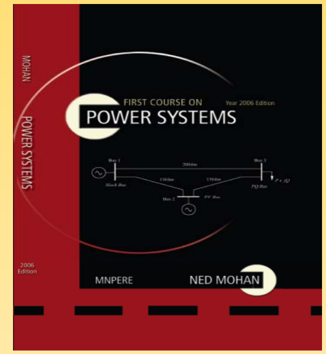
Power Electronics:



Electric Drives:



Power Systems:

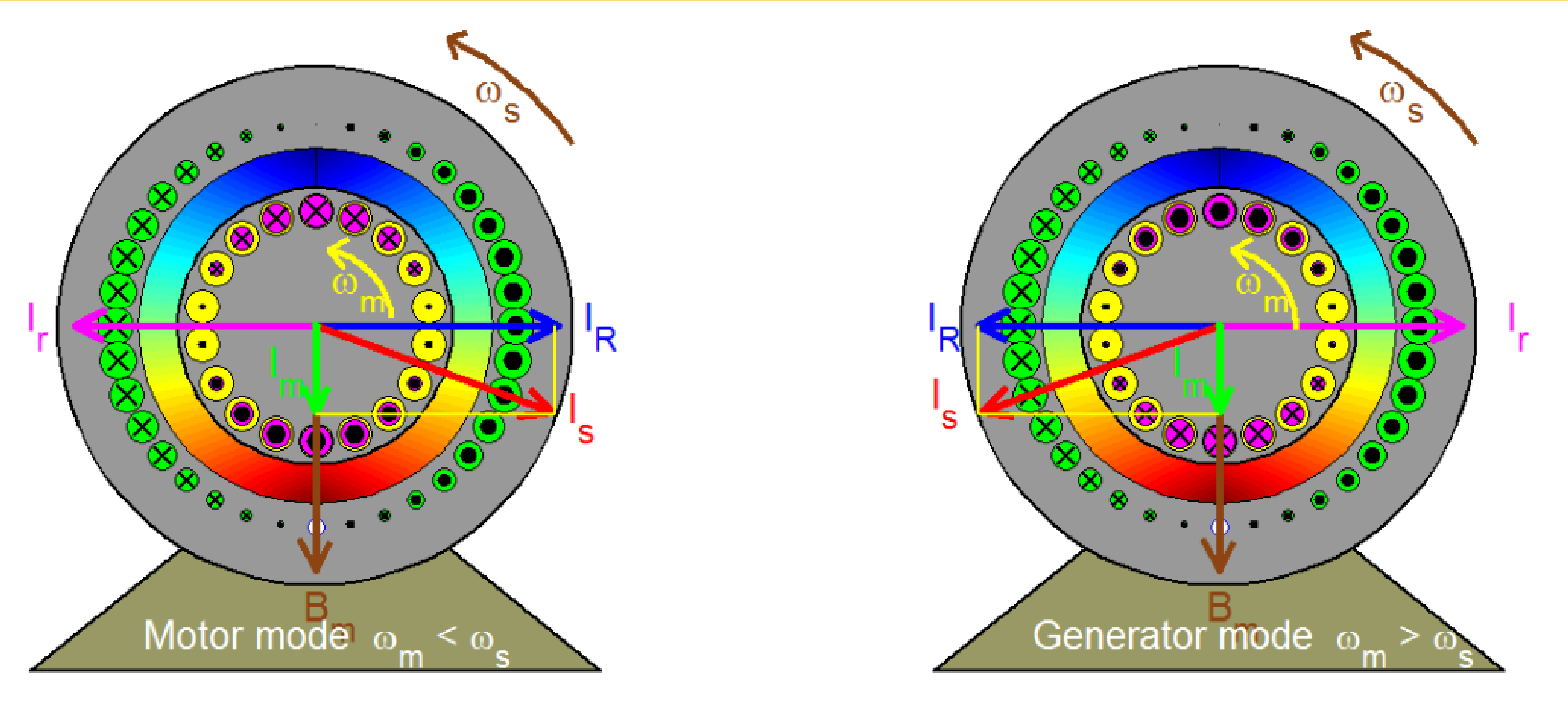


PSpice Lab:

Software Lab:

MATLAB/Simulink
PowerWorld
PSCAD-EMTDC

Animations by Prof. Riaz:

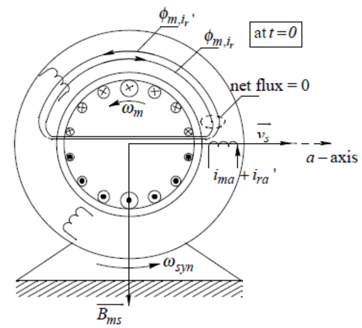


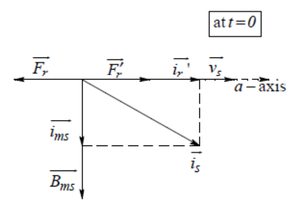
http://www.ece.umn.edu/users/riaz/animations/sqmoviemotgen.html

Instructor’s CD

Rotor MMF – Reflected Rotor MMF – Reflected Rotor Current

11-11





$$\vec{F}_s(t) = \vec{F}_{ms}(t) + \vec{F}_r'(t)$$
$$\vec{i}_s(t) = \vec{i}_{ms}(t) + \vec{i}_r'(t)$$
$$\hat{I}_r' = k_i \hat{B}_{ms} \omega_{slip}$$

- $\vec{F}_r$ produced by rotor currents
- $\vec{F}_r'$ produced by additional stator currents to keep total flux unchanged (transformer analogy)
- These currents are viewed as a current space vector $\vec{i}_r'$
- Total stator current is magnetizing current plus this reflected rotor current

Exit

Audio TOC ⇦ ⇨

UNIVERSITY OF MINNESOTA
Driven to Discover℠

Power Systems Lab:

Lab Manual - Experiments

1. Visit to a Local Substation/Generating Plant
2. Familiarization with PSCAD/EMTDC
3. Obtaining Parameters of a 345 kV Transmission Line and Modeling it in PSCAD/EMTDC
4. Power Flow using MATLAB and PowerWorld
5. Including Transformers in Power Flow using PowerWorld and Confirmation by MATLAB
6. Including an HVDC Transmission Line for Power Flow Calculations in PowerWorld and Modeling of Thyristor Converters in PSCAD/EMTDC
7. Power Quality
8. Synchronous Generators
9. Voltage Regulation
10. Transient Stability using MATLAB
11. AGC using *Simulink* and Economic Dispatch using *PowerWorld*
12. *Transmission Line Short Circuit Faults using MATLAB and PowerWorld, and Overloading of Transmission Lines using PowerWorld*
13. Switching Over-Voltages and Modeling of Surge Arresters using PSCAD/EMTDC

CD with 18 Video Clips

http://www.ece.umn.edu/groups/power/labs/ps/video_instructions.html

1. **Installation of PowerWorld and PSCAD-EMTDC**
2. **Familiarization with using PSCAD-EMTDC**
3. **Obtaining Parameters of Transmission Line using PSCAD/EMTDC**
4. **Simulating a Transmission Line in a Power System using PSCAD/EMTDC**
5. **Power Flow using PowerWorld**
6. **Power Flow using MATLAB**
7. **Including Off-Nominal Turns-Ratio and Phase-Shifting Transformers in Power Flow using PowerWorld**
8. **Including an HVDC Transmission Line for Power Flow in PowerWorld**
9. **Modeling of Thyristor Converters in PSCAD-EMTDC**
10. **Power Quality Calculations using PSCAD-EMTDC**
11. **Modeling of Synchronous Generators using PSCAD-EMTDC**
12. **Voltage Regulation by Thyristor Controlled Reactors (TCR) using EMTDC**
13. **Thyristor Controlled Series Capacitors (TCSC) using PSCAD-EMTDC**
14. **Transient Stability using MATLAB**
15. **AGC using *Simulink***
16. **Transmission Line Short Circuit Faults using PowerWorld**
17. **Tripping of Transmission Lines due to Overloads using *PowerWorld***
18. **Switching Over-Voltages and Modeling of Surge Arresters using EMTDC**

Software:
MATLAB/Simulink
PowerWorld
PSCAD-EMTDC

Online Courses

- Power Electronics
- Electric Machines/Drives
- Power Systems

- ◆ Modular
- ◆ Tightly-Coupled to our Textbooks
- ◆ CEUs/PDH
- ◆ Low Cost: $70/Module

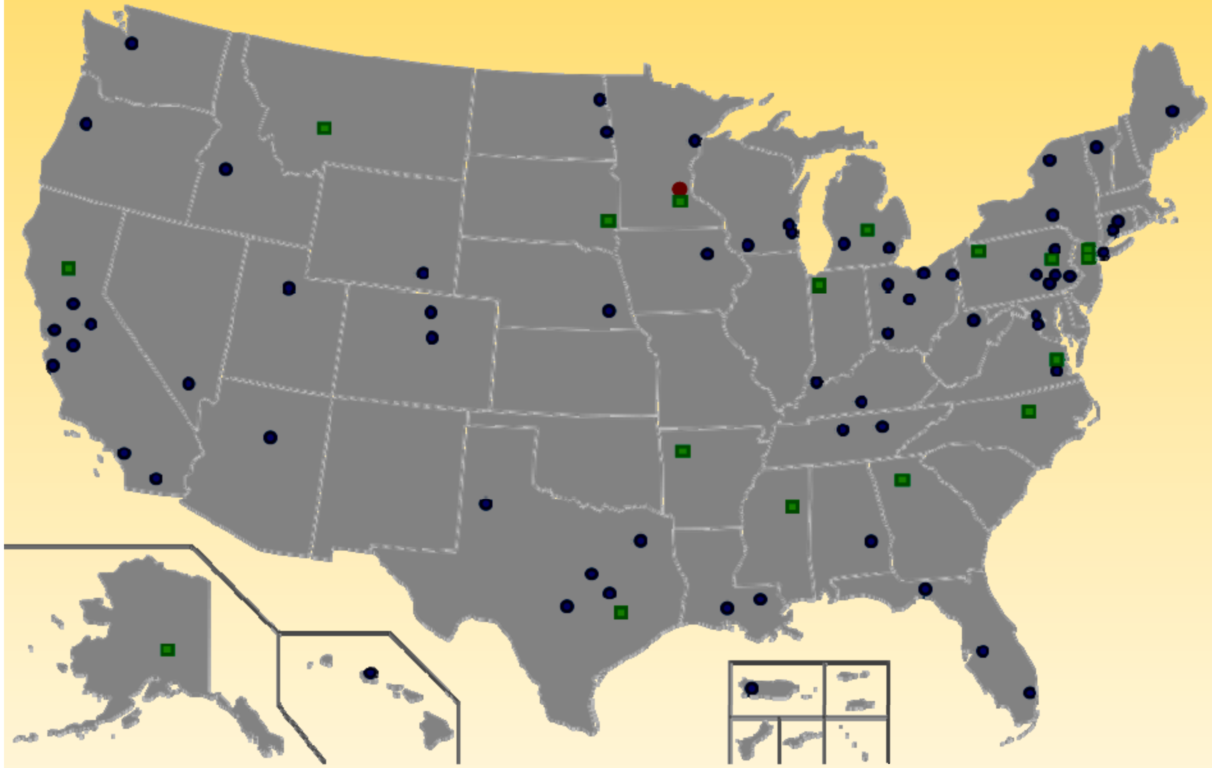
Use of Online Courses:

- Certificates for Practicing Engineers
- at other Universities (ABET: 432)

Pedagogy-

- Motivation:
  - Students are actively engaged
- Procedure:
  - Pre-class: watch a 20-minute module and answer a brief online quiz
  - During-class: discuss and solve real-world, design-oriented, somewhat open-ended problems in small groups
  - Post-class: homework problems on individual basis; based on Moodle

DOE Proposal Accepted:
“A Nationwide Consortium of Universities to Revitalize Electric Power Engineering”



82 Universities

“These 82 schools represented about 25% of all the graduates in electrical engineering in 2008.” – William P. Robbins

Still Smiling!