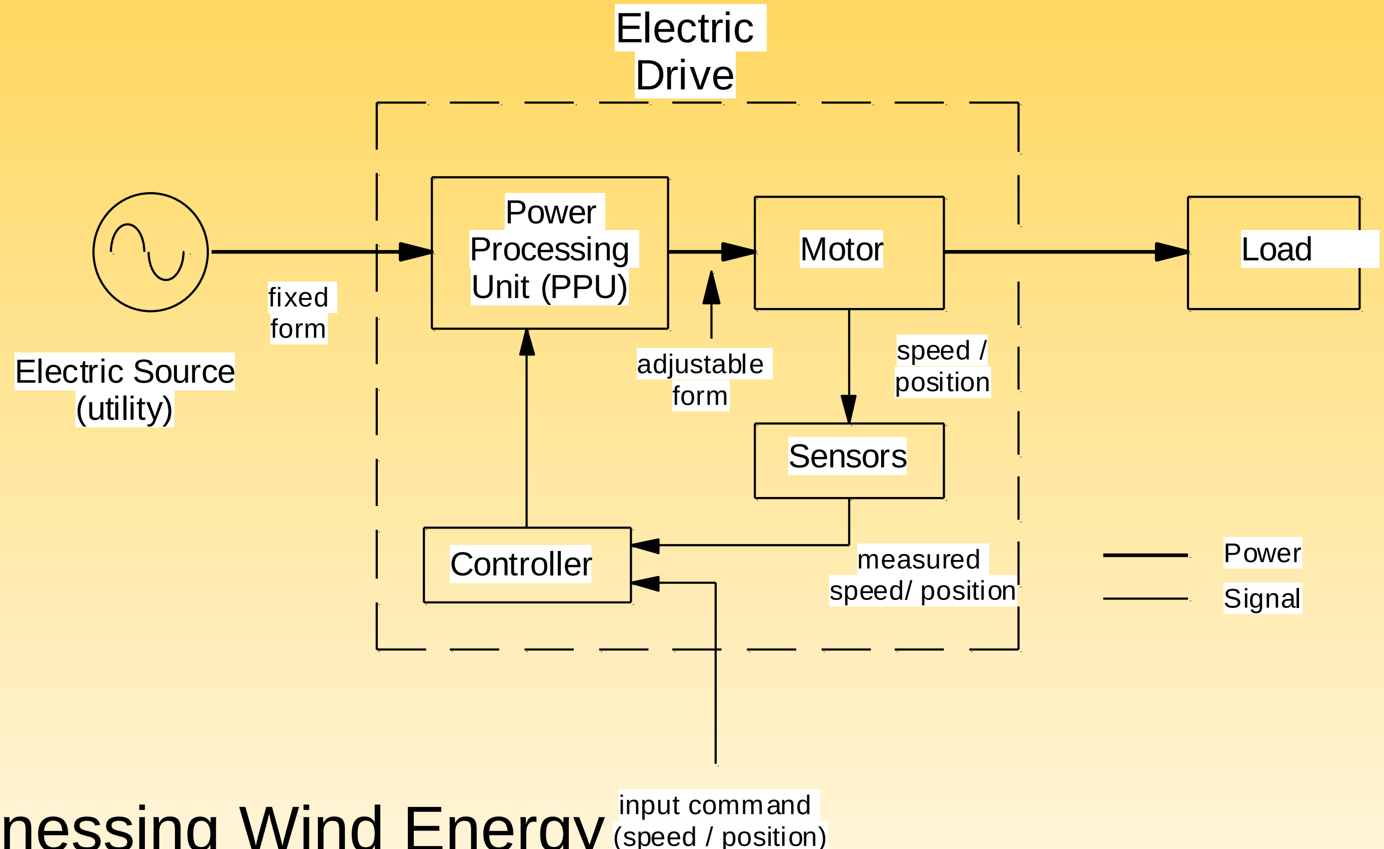
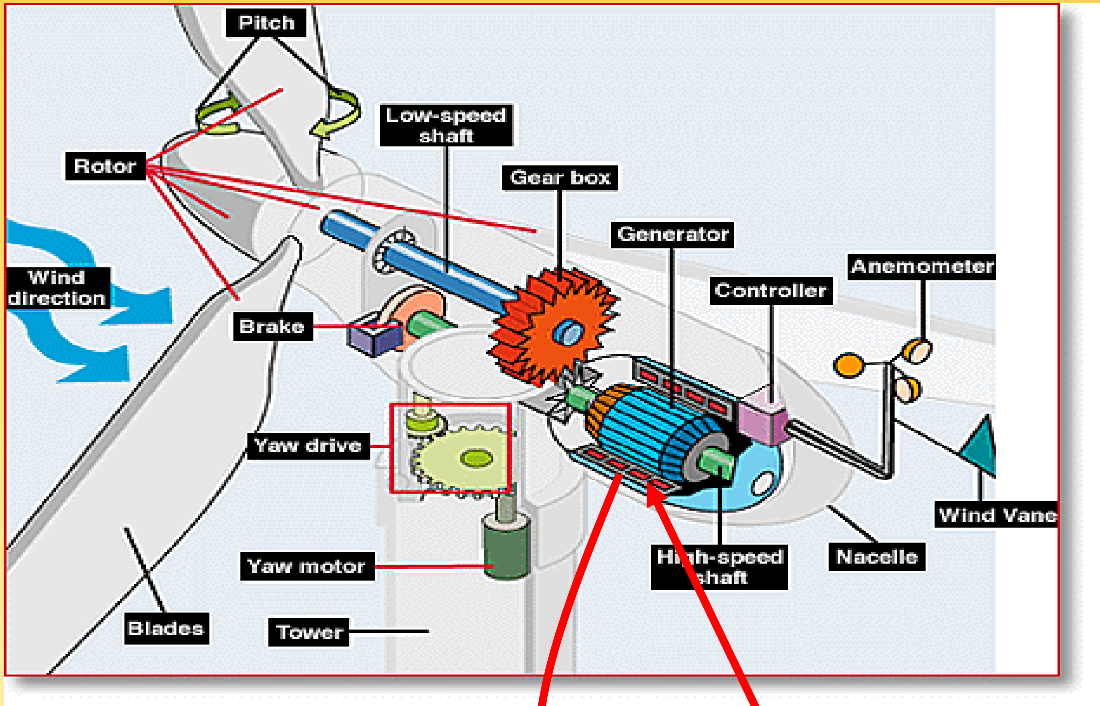
First Course on
Electric Drives

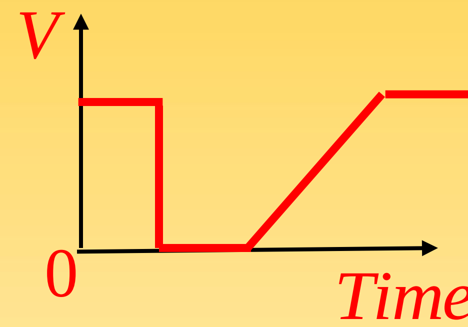


- Harnessing Wind Energy
- Electric and Hybrid-Electric Vehicles

Windmills: Example of an Integrated System



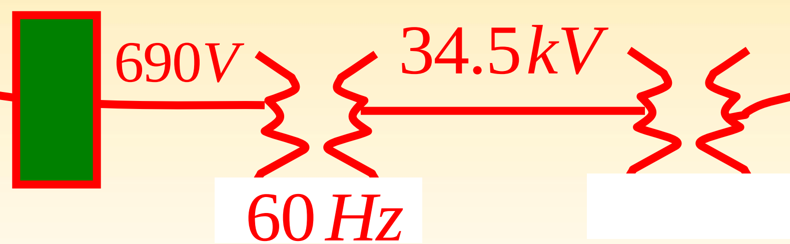
$161kV$



Low-Voltage
Ride-Through

$0 - 690V$
$10 - 60\,Hz$

Generator



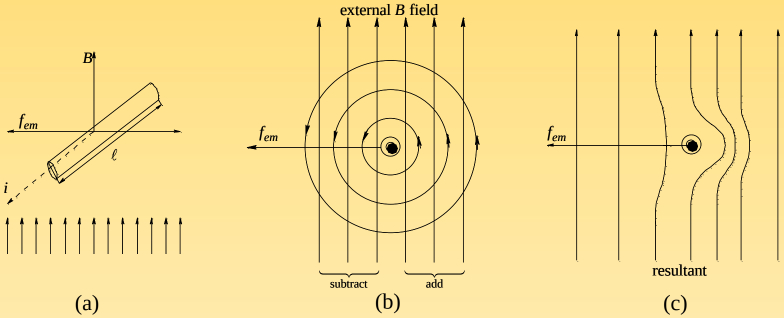
Power Electronics
Converters

Course Objectives

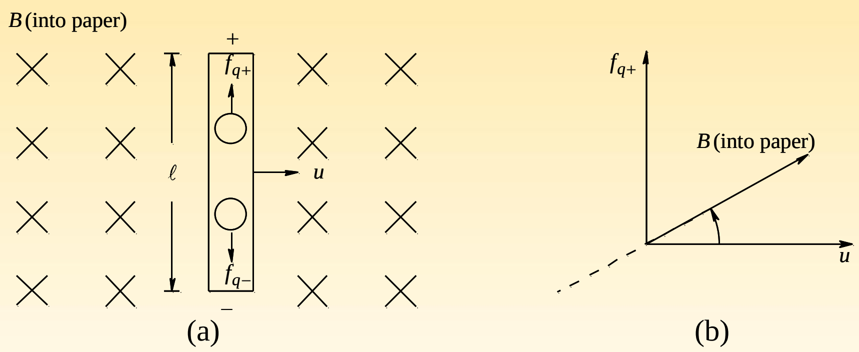
- Analyze
- Control
- System Design (not machine design)

Two Common Principles

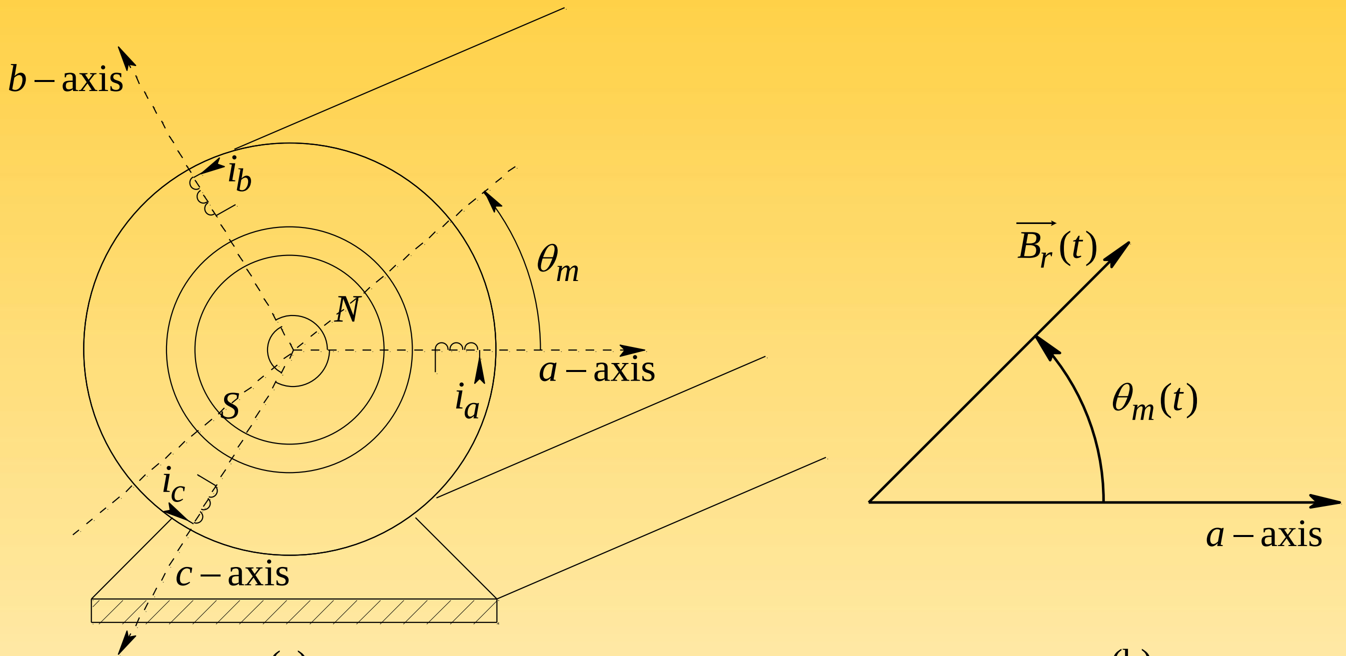
$$f_{em} = B\,i\,\ell$$



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

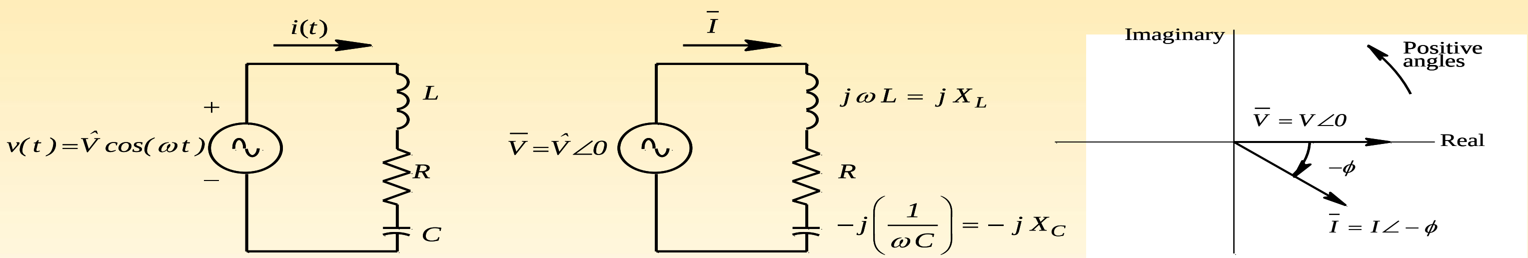


Use of Space Vectors



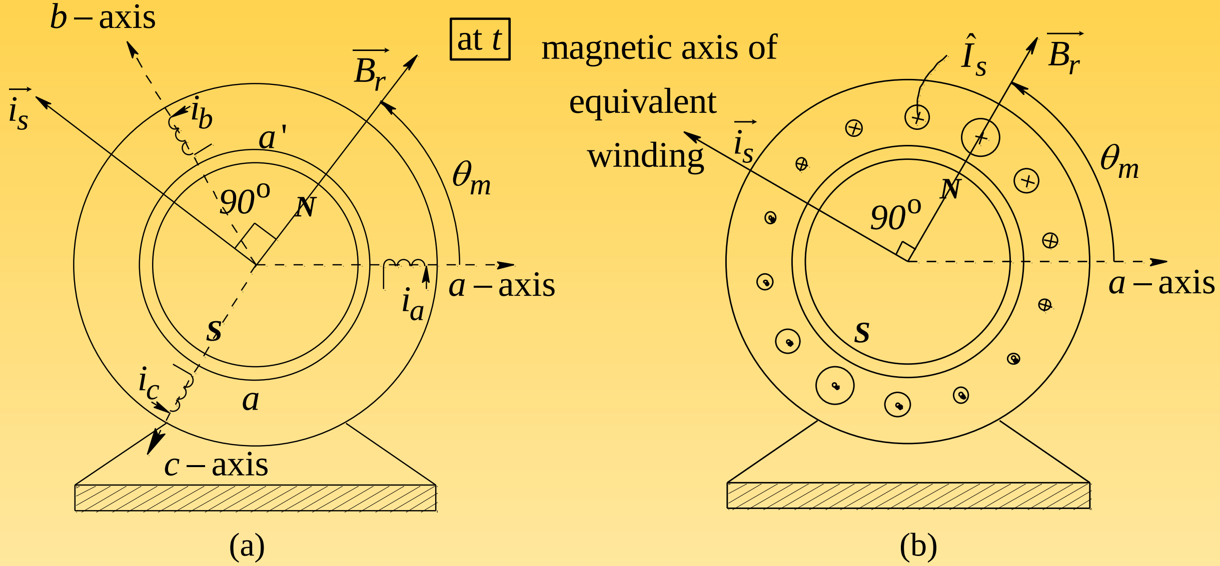
(a) (b)

Similar to use of Phasors



(a) (b) (c)

Physics-Based Analysis



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

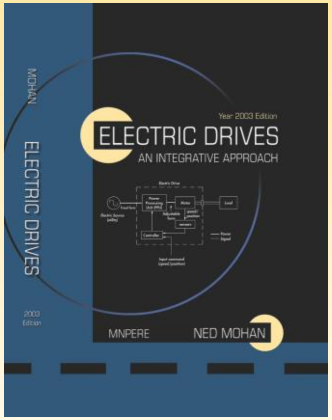
$$T_{em} = 2\times\int_{\xi=-\pi/2}^{\xi=\pi/2} dT_{em}(\xi) = 2\frac{N_s}{2}r\ell\hat{B}_r\hat{I}_s\int_{-\pi/2}^{\pi/2}\cos^2\xi\cdot d\xi = (\pi\frac{N_s}{2}r\ell\hat{B}_r)\hat{I}_s$$

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

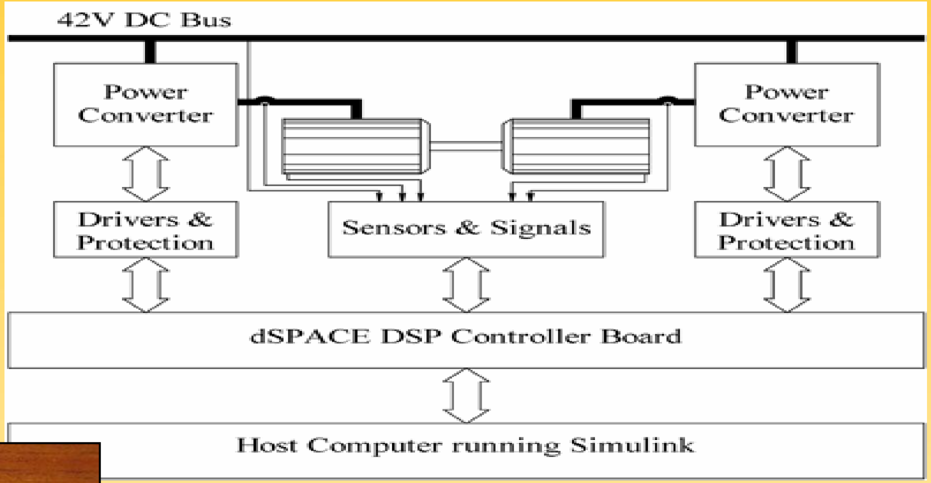
Textbook

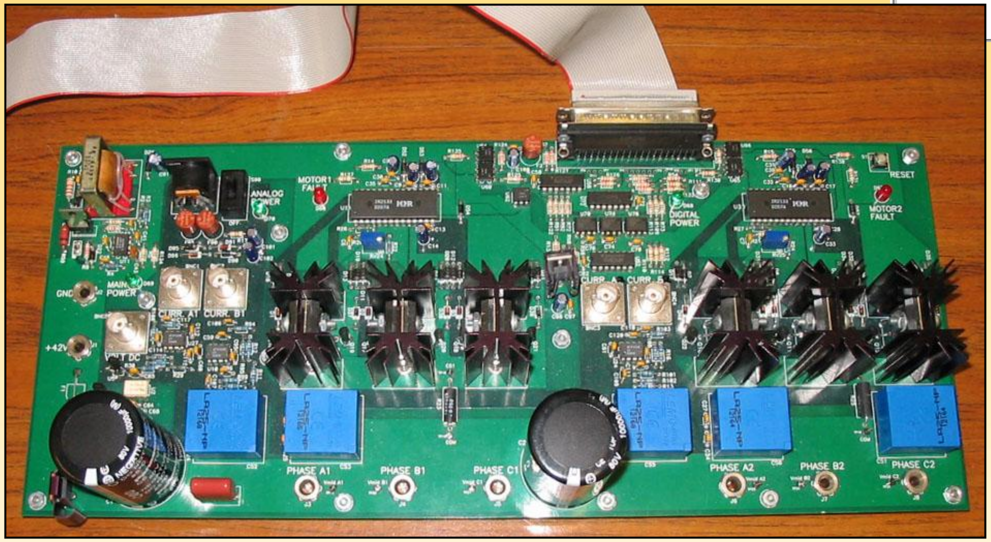
- Presentation Slides
- Solutions Manual



Electric Drives Lab

- Low-cost; 42-V no Shock Hazard!
- DSP Controlled; easy to use
- Active Load Allows Experiments otherwise not possible
- Very Popular with students!





Drives Board for Motor and Active Load (Generator)

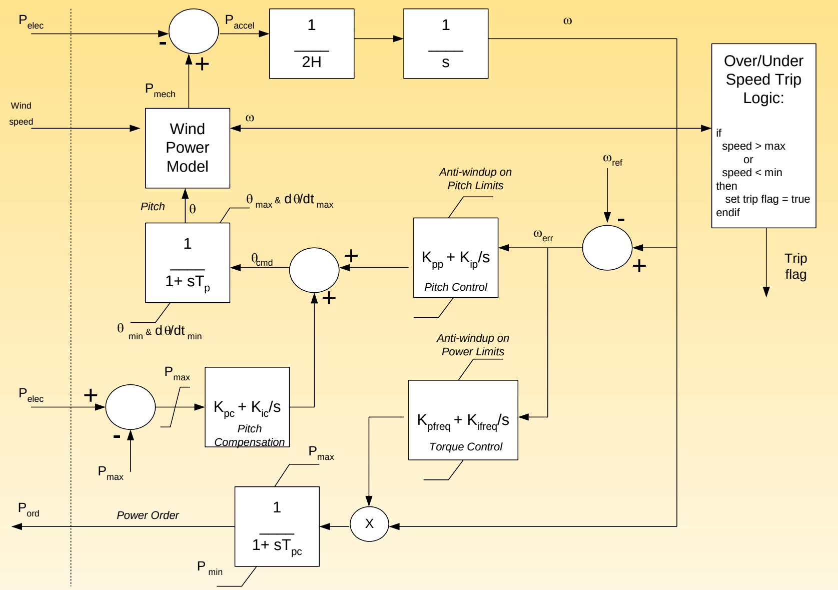
42 - V Motor Set

Graduate-Level Course

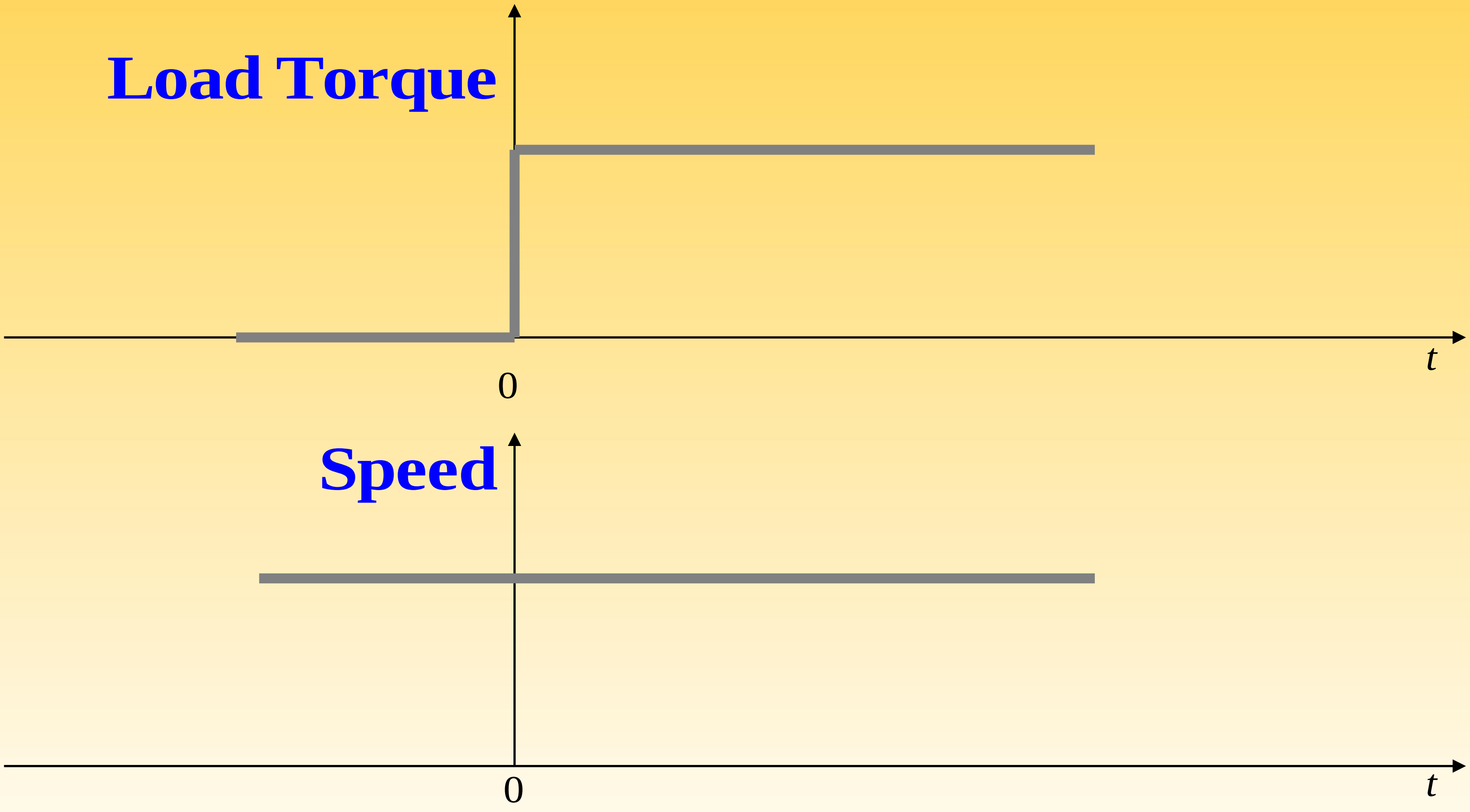
d-q axes control

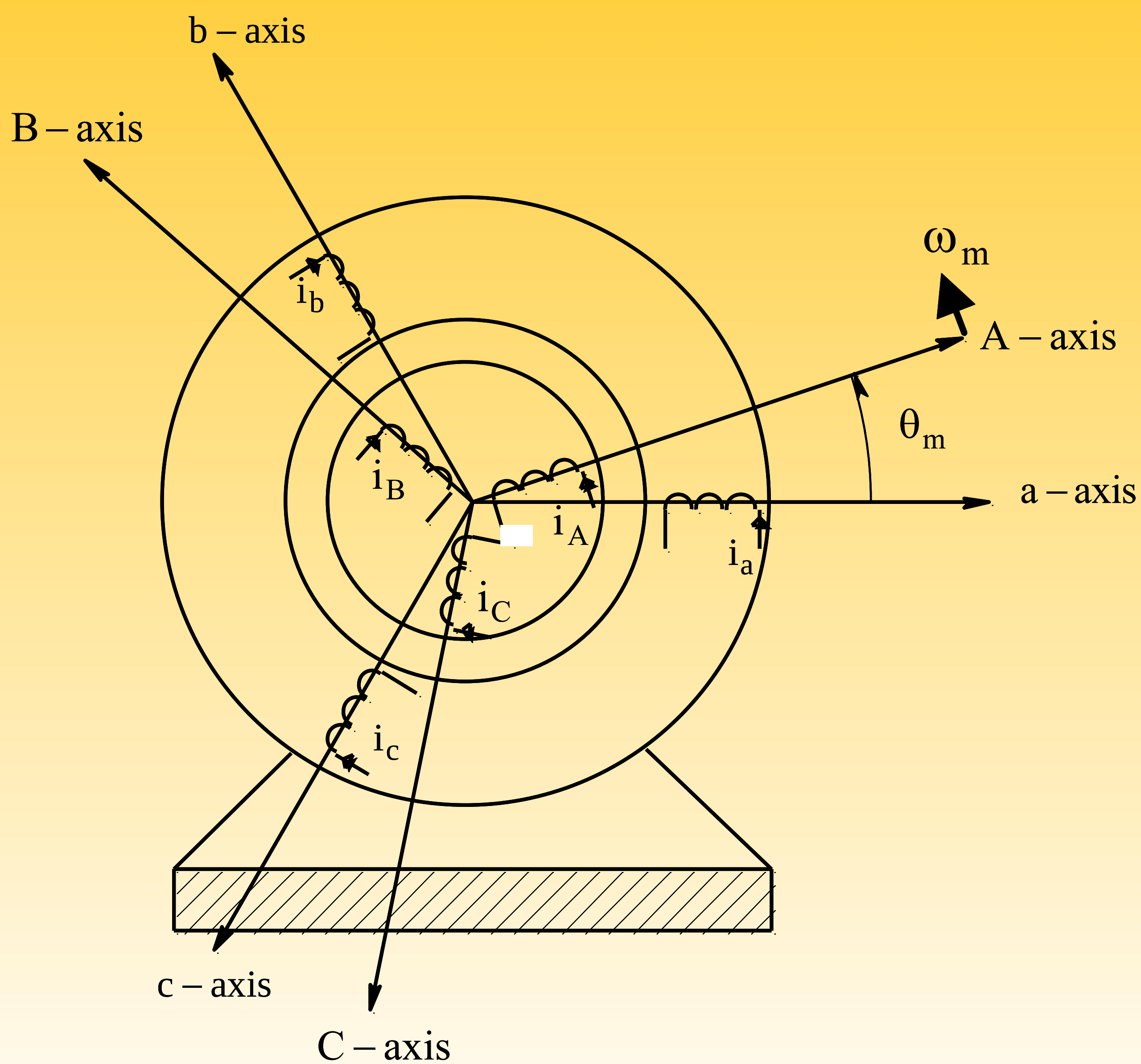
Applications in windmills, hybrid and electric vehicles, robotics and factory automation

Control of Drives in Windmills



Seamless Transition to Dynamic Control and Encoderless Operation




b – axis
B – axis
ω m
A – axis
θ m
a – axis
i b
i B
i A
i a
i C
i c
c – axis
C – axis

Mutual Inductance Between dq Windings on Stator and Rotor

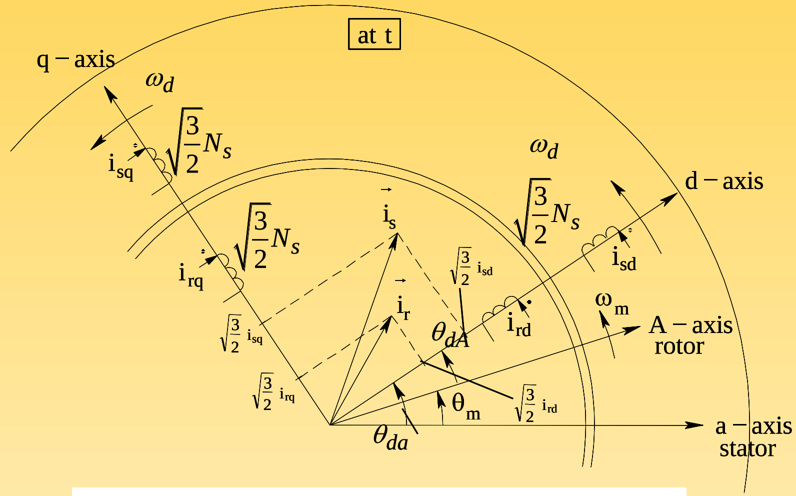
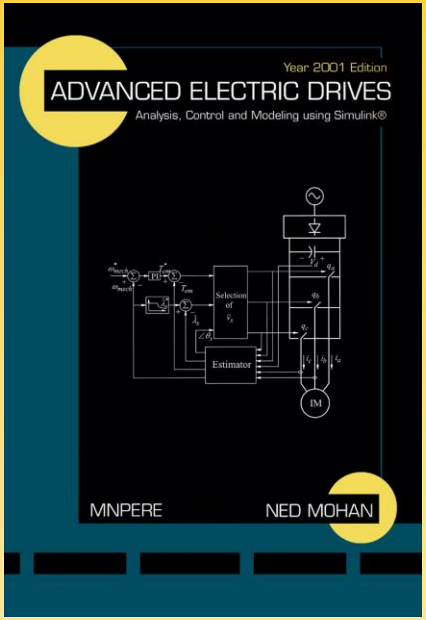


Figure 3-3 Stator and rotor representation by equivalent *dq* winding currents. The *dq* winding voltages are defined as positive at the dotted terminals. Note that the relative positions of the stator and the rotor current space vectors are not actual, rather only for definition purposes.

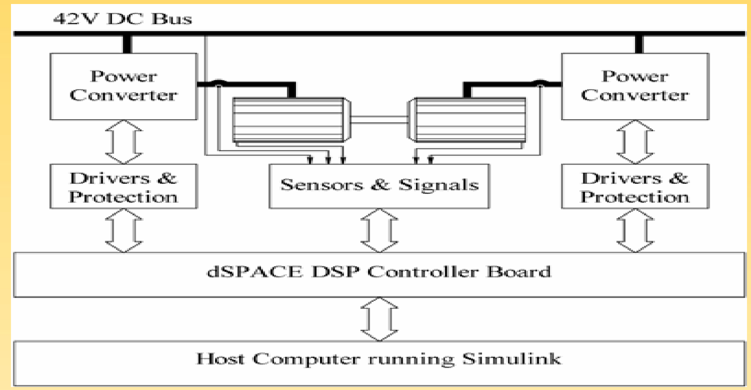
$$\lambda_{sd} = L_s i_{sd} + L_m i_{rd} \qquad \lambda_{rd} = L_r i_{rd} + L_m i_{sd}$$

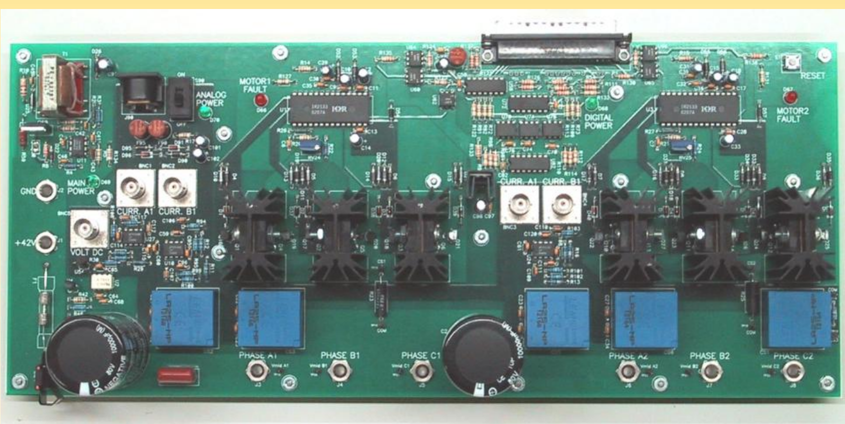
$$\lambda_{sq} = L_s i_{sq} + L_m i_{rq} \qquad \lambda_{rq} = L_r i_{rq} + L_m i_{sq}$$



Graduate Level Course

- Low-cost
- **42-V no Shock Hazard!**
- DSP Controlled; easy to use
- Active load allows experiments not otherwise possible





Drives Board for Motor and Active Load (Generator)

42 - V Motor Set