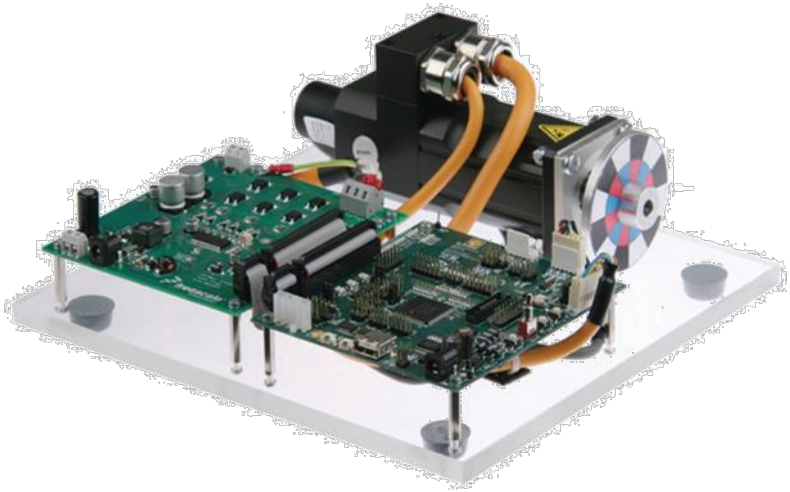
Chapter 0

Course Overview



Professor Min-Fu Hsieh

Fall Semester - 2022

https://www.arrow.com/en/reference-designs/mtrcktsps5604p-3-phase-pmsm-motor-control-development-kit-with-qorivva-mpc5604p-mcu/86eb9dbe0c4a1f3ef0646322dd405812

Declaration

"All the pictures and diagrams are only used for educational purpose. Their copyrights belong to the authors/creators themselves"

What is an Electrical Drive?

- The system which is used for controlling the motion of an electrical machine is called an electrical drive.
- An electrical drive consists of power modulator, control unit and sensing unit.
- Direction of energy flow can be two-way. (Traction/ Regen vs ISG)
- For use with electric motors, it can be called motor drive.
- Classification:
  - **Standard inverter drive**: controlling speed and torque (power), sending corresponding electric power, voltage, frequency, current to motor.
  - **Servo drive**: controlling speed and torque, as well as positioning machine components used in applications that require complex motion.

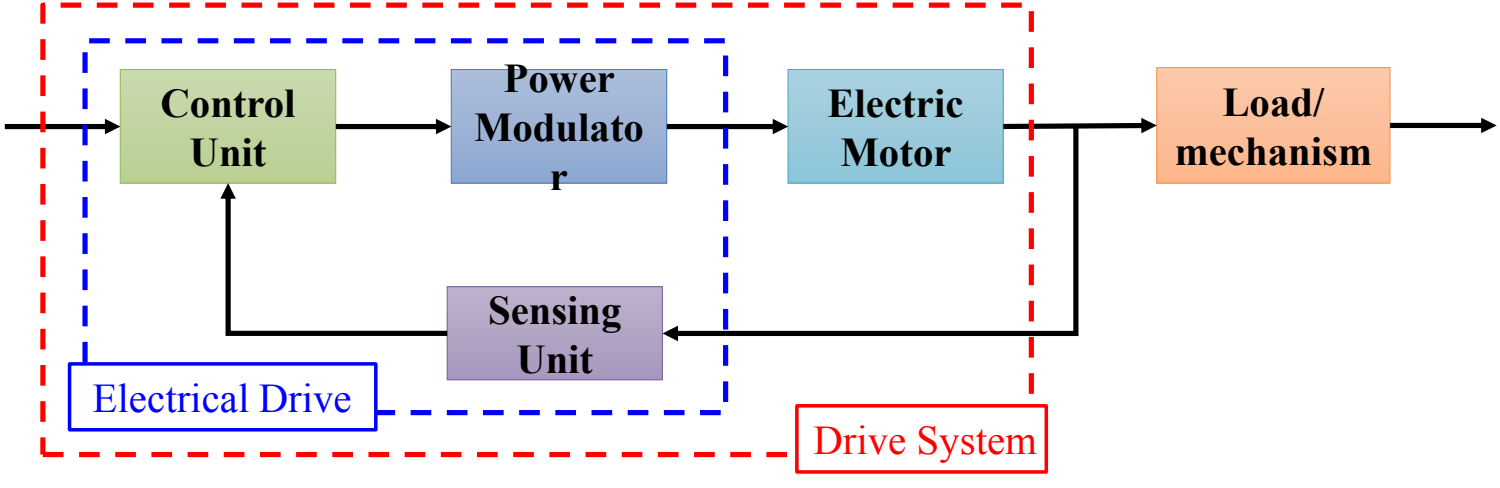
What is an Electrical Drive?

Ex: MCU, DSP, FPGA,…

Ex: Inverter, Rectifier,…

Ex: DC motor, PMSM, SynRM

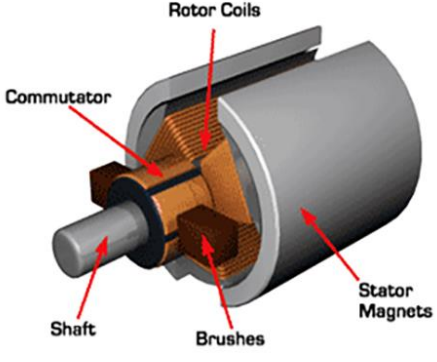
Ex: Car, bus, train, motorcycle…

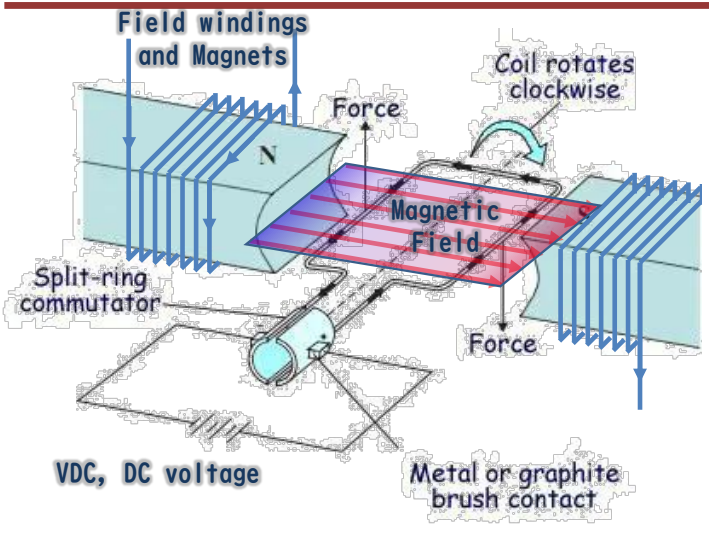


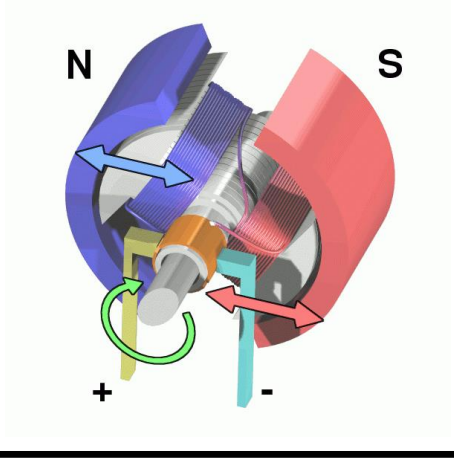
Ex: Speed, current, voltage sensor…

Why we need an Electrical Drive?

Brushed DC Motor



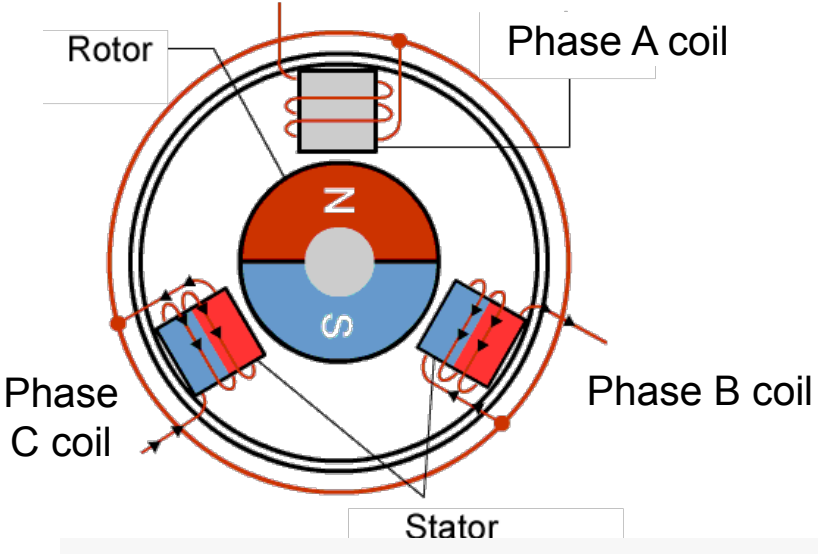


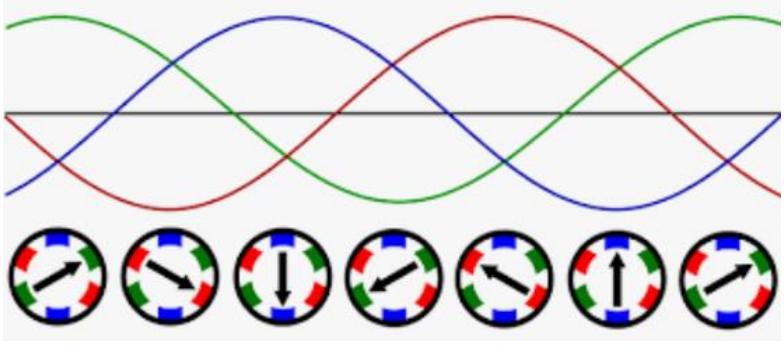


Control the DC voltage to adjust the armature current. The magnets and field windings are also controlled to generate stable magnetic field. The output of the DC brushed motor is controll by the ***magnitude of input voltage***.

Commutator is required to control the angle of the armature current. The intermittent contact generates arcs, and high-speed friction causes heat and damage, so it is consumable device.

Why we need an Electrical Drive?





Synchronous Motor

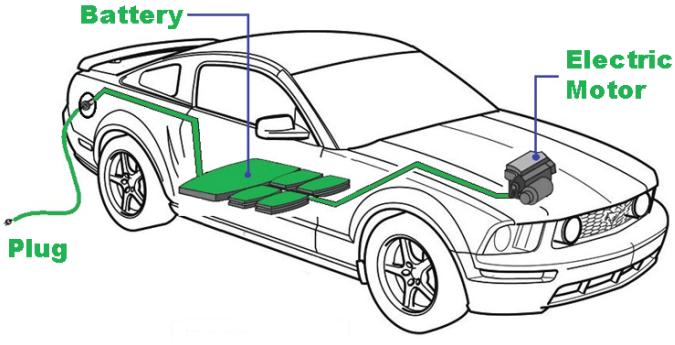
GIF in the left is an three phase Permanent Magnet Synchronous Motor (PMSM) with 2 poles and 3 slot, which is the basic 3 phase motor.
The magnet is set on rotor, so field is spinning with rotor.

The drive need to generate an AC voltage with ***controlled amplitude*** ***and*** ***frequency***, and power it into the stator coils with the ***correct phase with rotor angle*** to drive the PMSM.

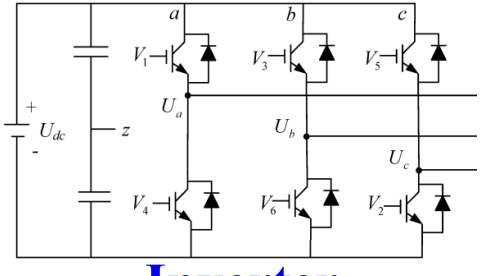
So the motor drive needs to be a combine with convert and an inverter, which can be achieved with power electronics.

GIF picture source:
https://www.embitel.com/blog/embedded-blog/brushless-dc-motor-vs-pmsm-how-these-motors-and-motor-control-solutions-work

Why we need an Electrical Drive?



Power Source: Battery (DC Power)



Inverter

DC → **AC**

Microcontroller

Battery

Motor

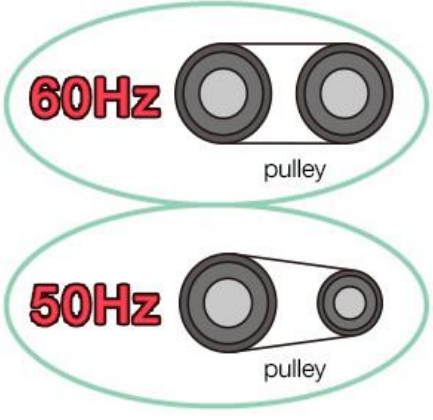
Advantages of Drives (Variable Speed)

- A variable speed drive can reduce energy consumption by as much as 60%. For a 90 kW motor in continuous duty, this can mean over £9,000 per year. This is because the variable speed drive reduces the amount of energy drawn by the motor.
- Even a small reduction in speed can give significant savings. For instance, a centrifugal pump or fan running at 80% speed consumes only half of the energy compared to one running at full speed

© ABB *http://www.abb.com/cawp/seitp202/c253ae5e6abf5817c1256feb0053baf7.aspx*

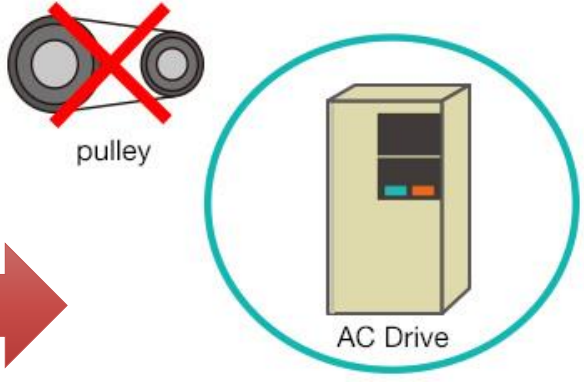
Advantages of Drives (Stable system)

Without Drive



Flexible

With Drive



Without Drive

Speed/Torque
Changing Suddenly

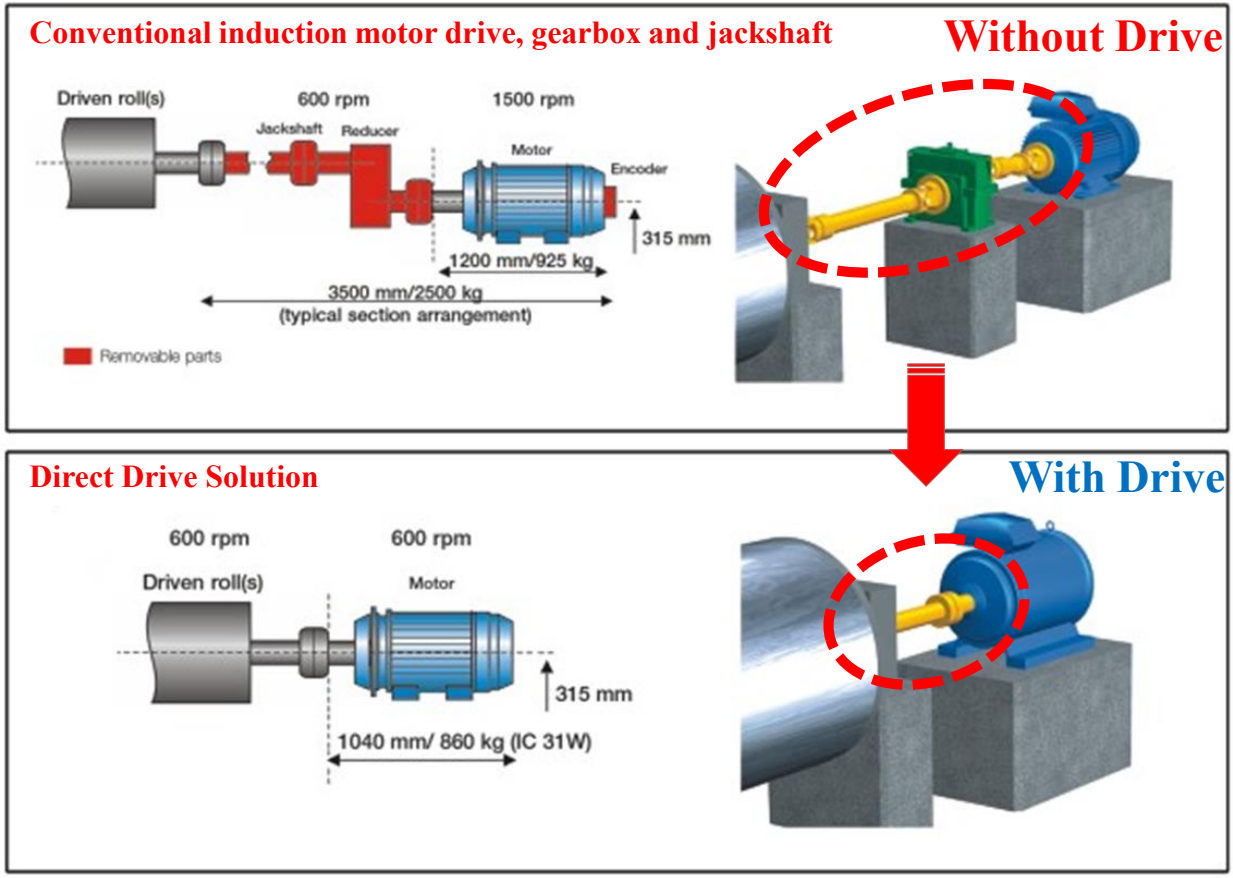
Reliability

With Drive

Speed/Torque
Changing Smoothly

https://www.yaskawa-global.com/product/ac/about

Advantages of Drives (Complexity savings)



https://www.techbriefs.com/component/content/article/tb/techbriefs/electronics-and-computers/7655

Applications (Traction System)

http://greatecology.com/high-speed-railways-bird-mortality/

https://www.tesla.com/modelx

https://www.greenbiz.com/article/its-rush-hour-urban-electric-buses

https://www.gogoro.com/

Other Applications

Main Things to Learn In This Course

Brief introduction to electromechanical energy conversion and electric motor principle based on Permanent Magnet Synchronous Motor (PMSM) and build up motor mathematic model.

Motor parameters required for drive.

Typical techniques of pulse width modulation (PWM).

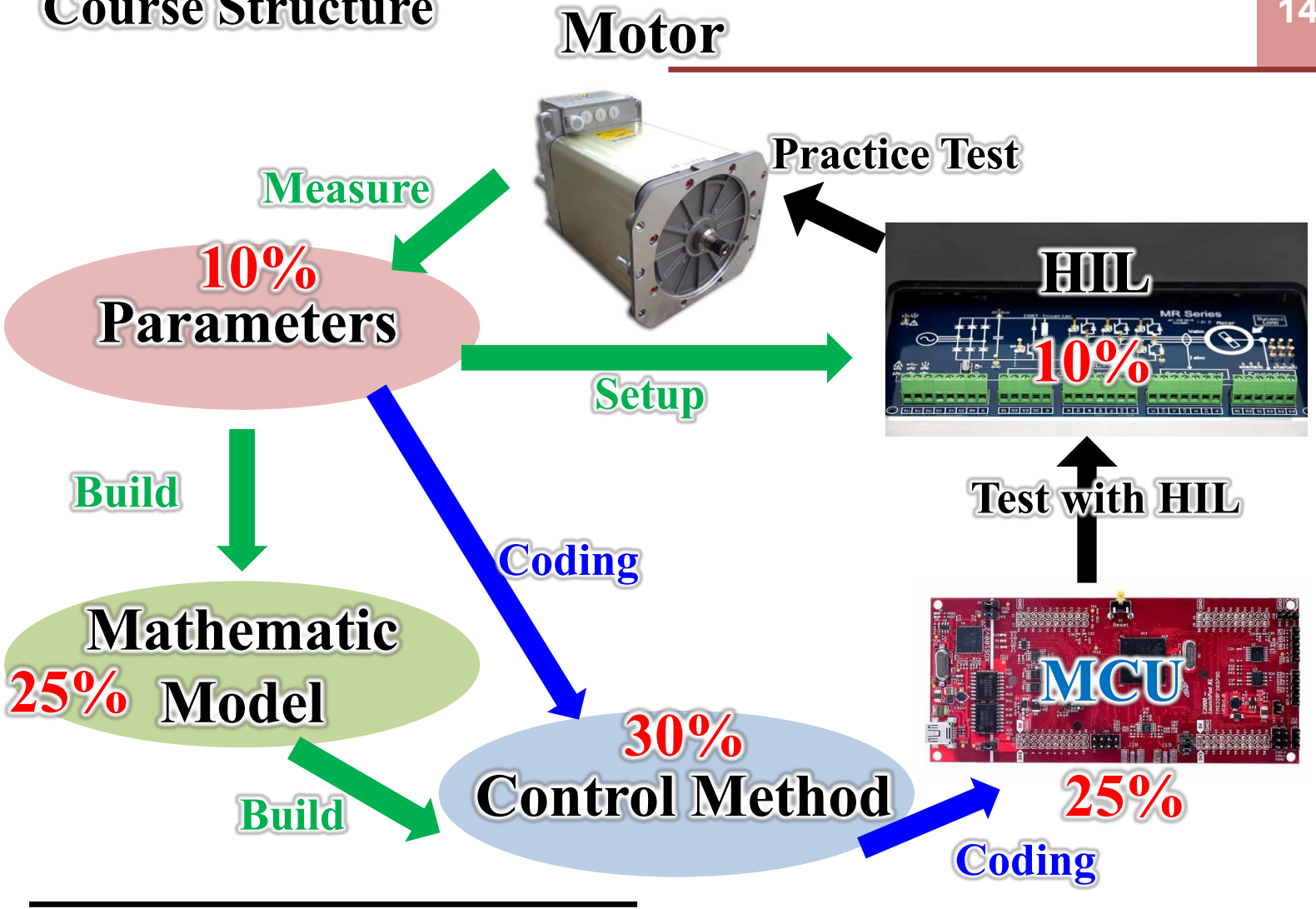
Vector control methods for drive PMSM.

Application of Micro-control unit (MCU) to motor drive and implementation (by composing control programs) of vector control to drive a virtual motor model or real electric motor.

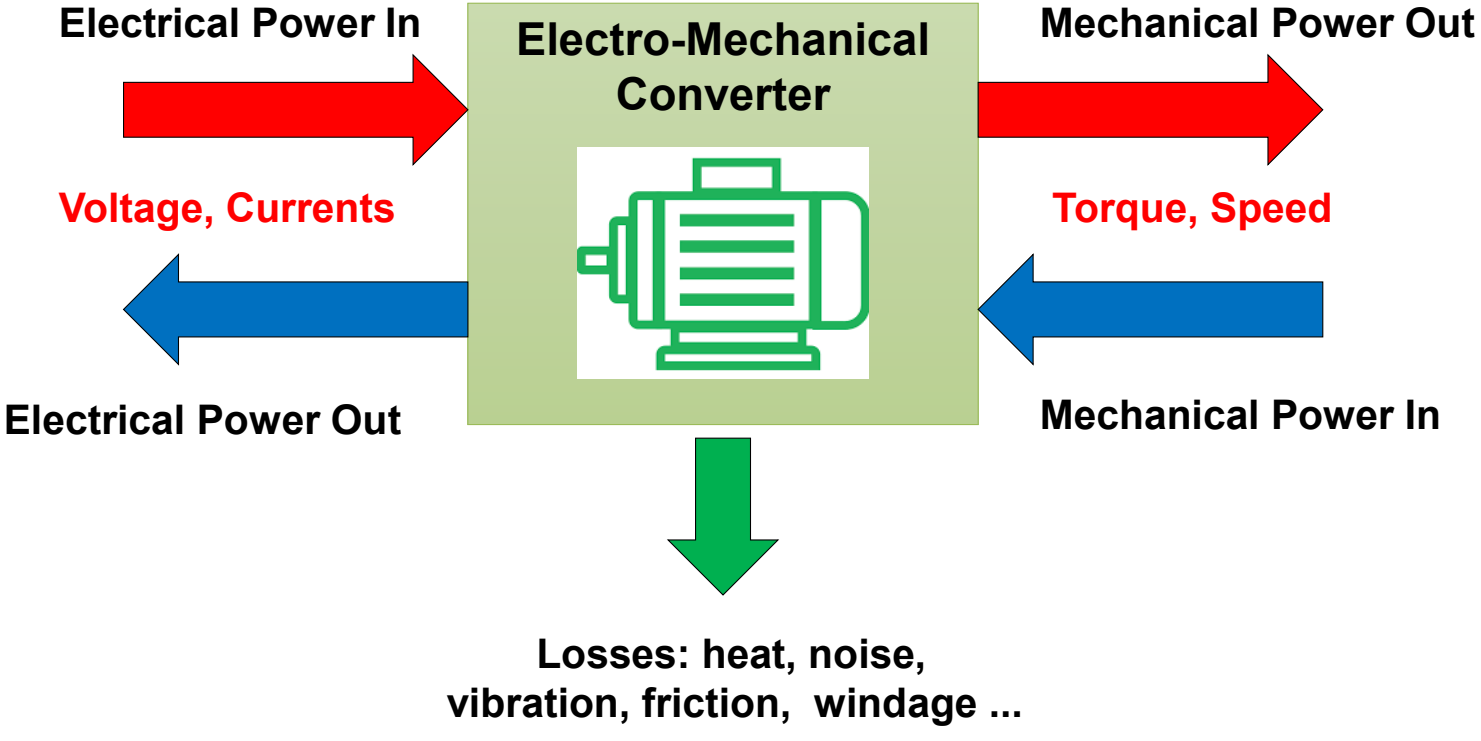
MATLAB Simulink simulation and Hardware-in-the-loop (HIL).

** Servo drive NOT included in this course.*

Course Structure

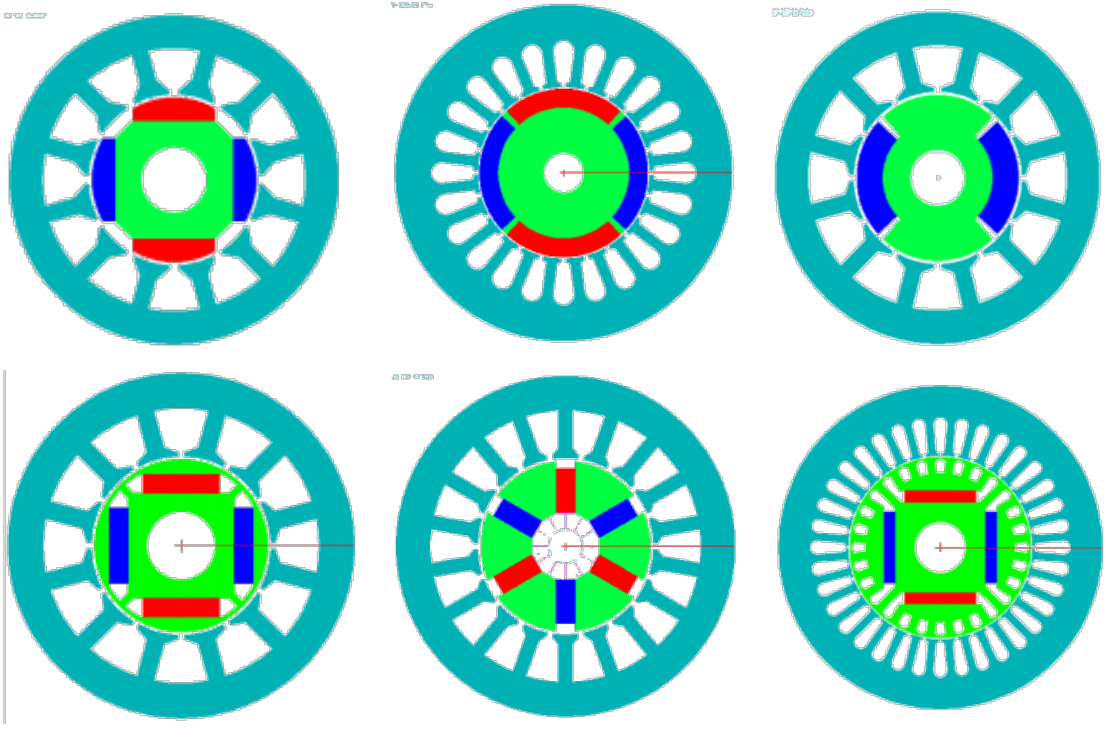


What to Study

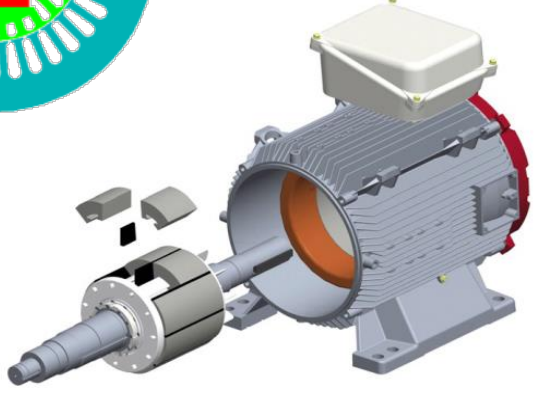


The significance of electric machines is "energy conversion"

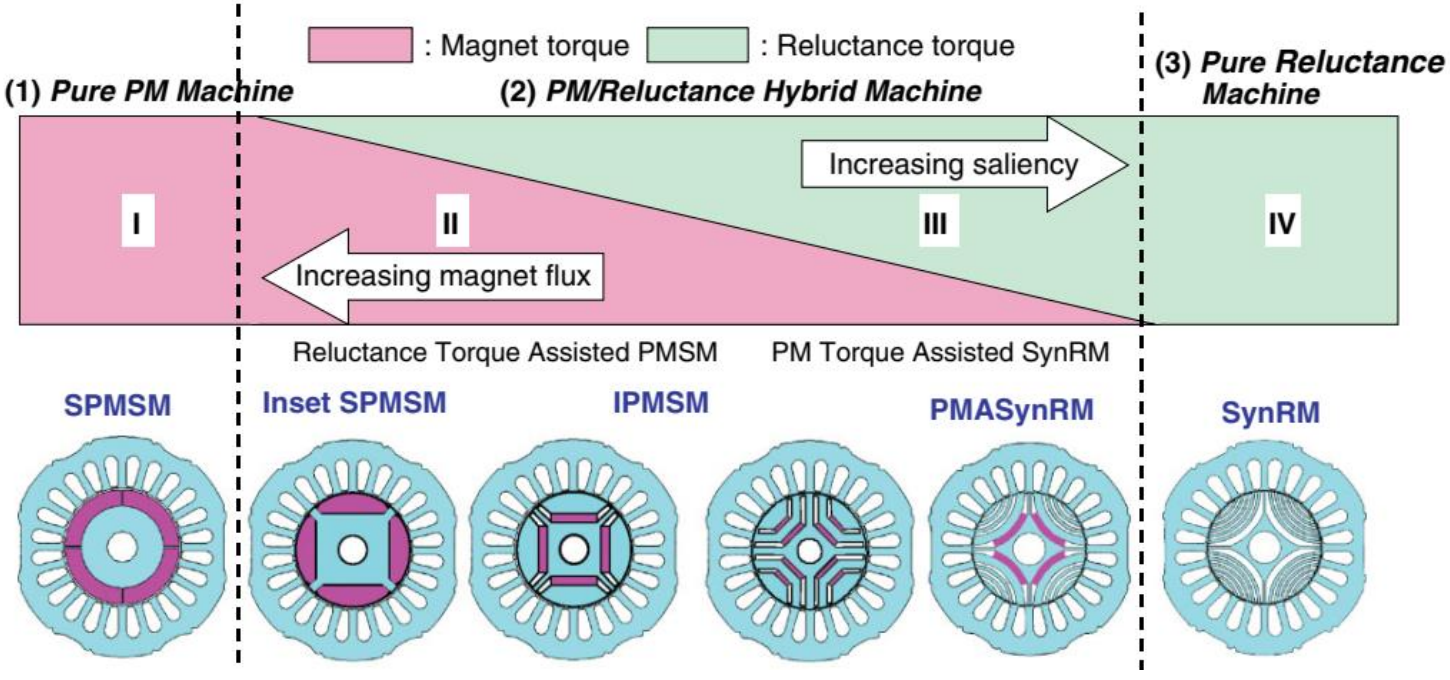
What to Study



Permanent Magnet Synchronous Motor (PMSM)



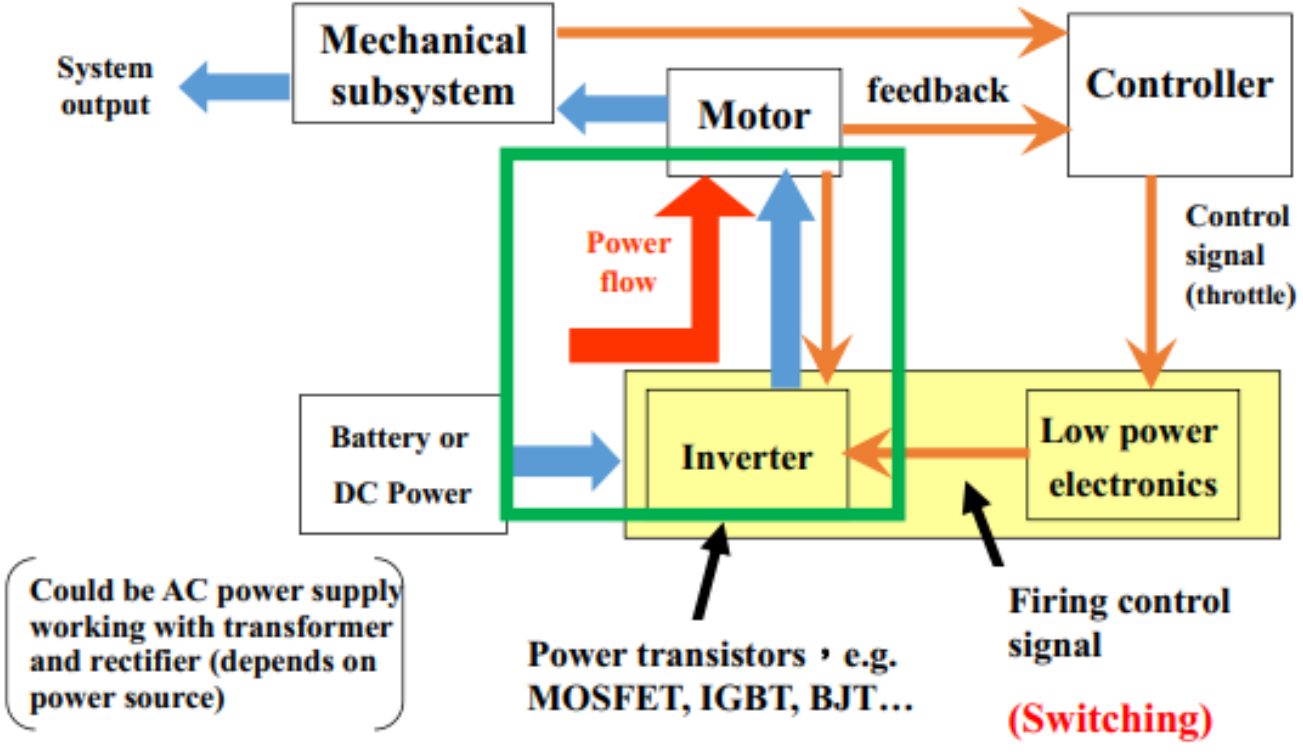
Classification of Synchronous Machines



Classification of synchronous machines by torque generating mechanism

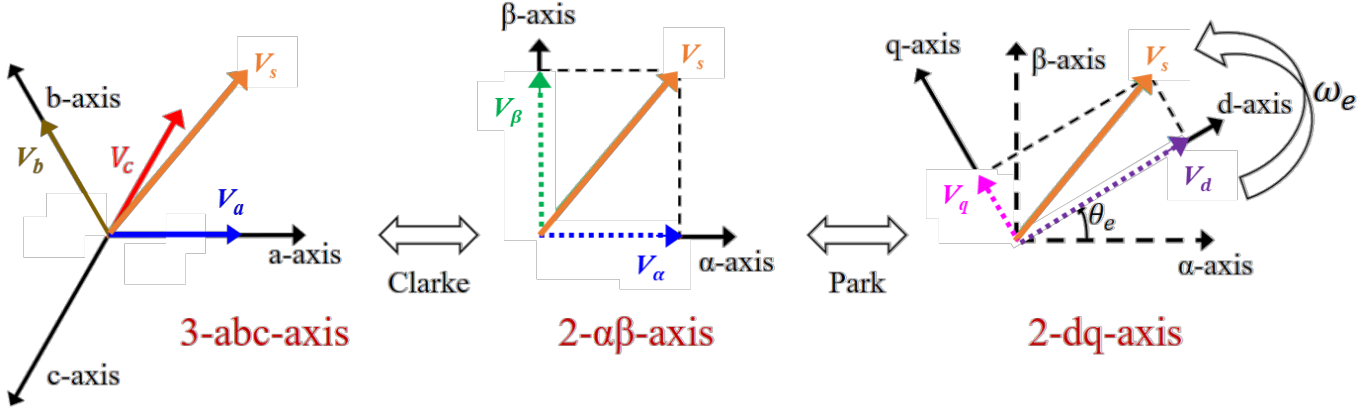
Shigeo Morimoto*[a], **"Trend of Permanent Magnet Synchronous Machines",** IEEE Transactions On Electrical And Electronic Engineering, 2007; 2: 101–108

What to Study

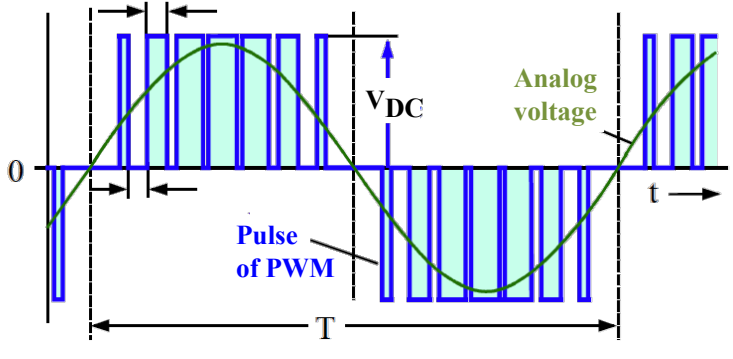


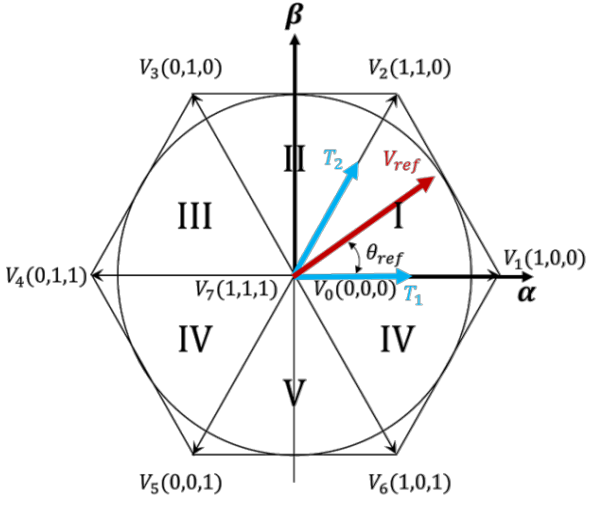
What to Study

- **Clark & Park Transformation**

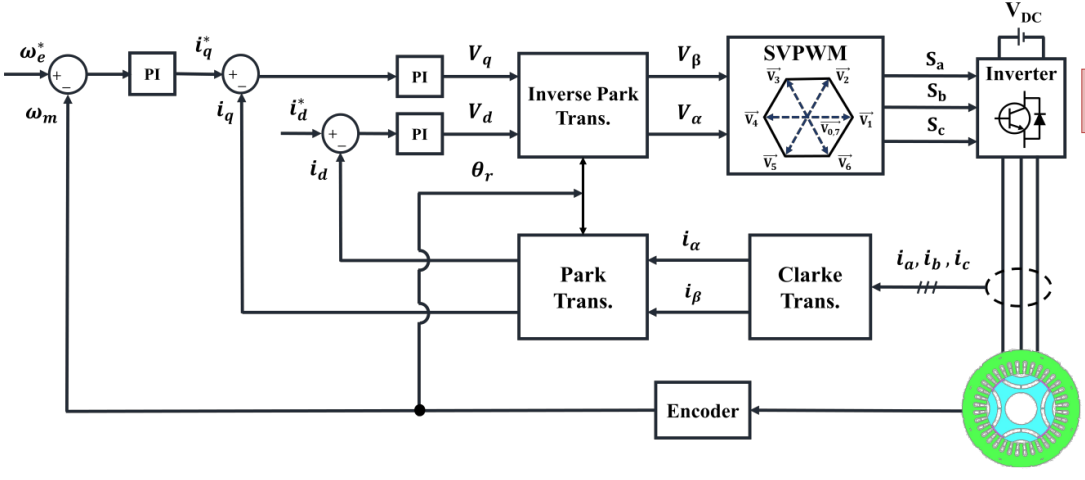


- **SPWM & SVPWM**

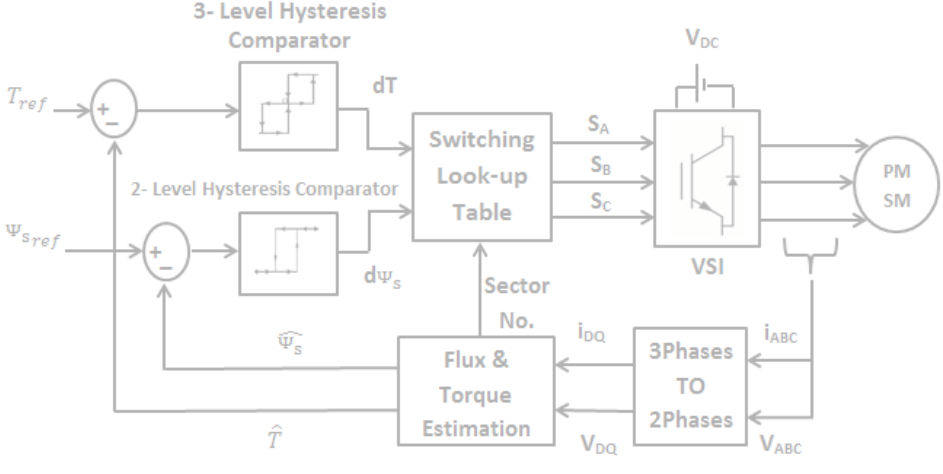




Vector Control Method

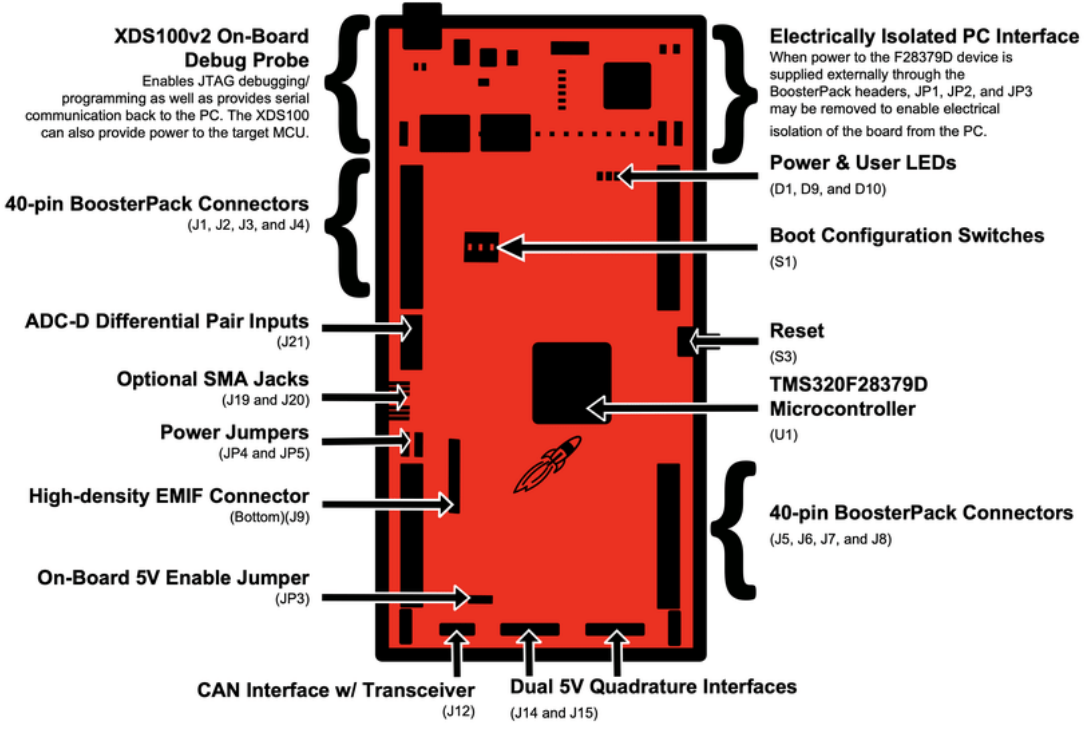


Field-Oriented Control (FOC)



Direct Torque Control (DTC)

What to Study

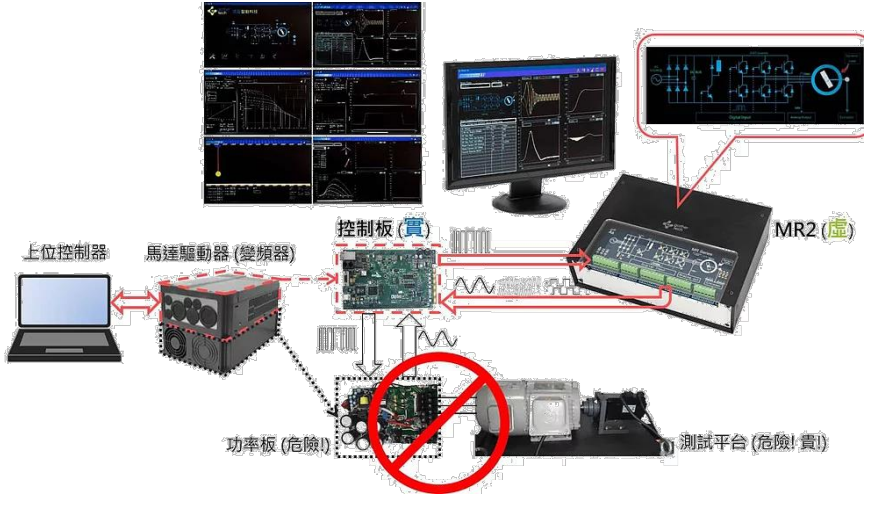


TI LaunchPad™ LAUNCHXL-F28379D

6: Tarjeta LAUNCHXL -F28379D [44] | Download Scientific Diagram (researchgate.net)

Learning Facilities

- Simulation Software: ®MATLAB/ Simulink
- Micro-Controller (MCU): ®Texas Instruments – Development Kit (LAUNCHXL-F28379D)
- ®GatherTech MR2 Hardware-in-the-loop (HIL)

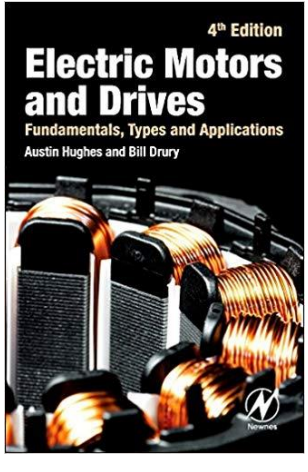


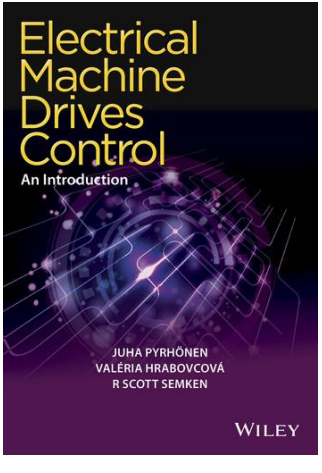
Course Content

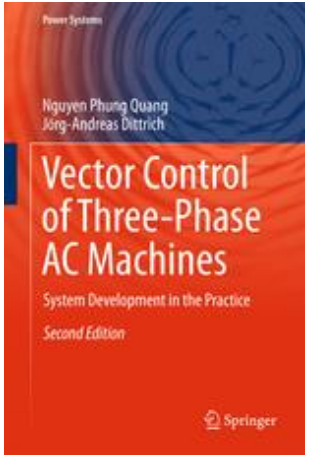
Week		Schedule	Practice	Material
01	09/06	Lecture: Drive configuration & Electric machinery	group, download material from Moodle	CH0,1
02	09/13	Practice: Install CCS & Create project & I/O function	Build an I/O project	H1
03	09/20	Practice: Interrupt & Timer	Write a marquee	H2
04	09/27	Practice: Pulse width modulation & Switching dead time	Make a breathing light	H3
05	10/04	Practice: Analog to digital conversion & Zero correction	Control PWM by ADC	H4
06	10/11	Lecture: Single-phase DC machine & Four basic formulas	Simulate the four-formula motor model	CH2
07	10/18	Lecture: Three-phase brushless motor & Six step square wave	Quiz (Basic Motor Theory)	CH2
08	10/25	Practice: Measure motor signal & Build drive table	Build the drive table	H5
09	11/01	Practice: Six Step drive method & Drive demo & Midterm rules	Midterm, simulate six-step	H6
10	11/08	Lecture: Sinusoidal pulse modulation & Park Clarke transformation	Midterm, drive TECO56 motor	CH3
11	11/15	Lecture: Space Vector PWM & Direct field-oriented control		CH3,4
12	11/22	Practice: encoder & eQEP & PCT & SVPWM	Write code, PCT & SVPWM	H7
13	11/29	Lecture: FOC Decoupled Control Architecture	Simulate direct FOC	CH4
14	12/06	Practice: Digital controller & FOC	Program PCT & SVPWM & FOC	H8
15	12/13	Lecture: Current angle & Phase advance & Field weakening control	Quiz (FOC Theory)	CH5
16	12/20	Lecture: Circle diagram & MTPA	Simulate MTPA	CH5
17	12/27	Practice: MTPA simulation & Demo HIL & Final test rules	Final exam, HIL test	H9
18	01/03	Practice: Final test	Submit final exam report	

Textbook and References

- *Austin Hughes and Bill Drury, "**Electric Motors and Drives: Fundamentals, Types and Applications (4th)**," Oxford, 2013.*
- *Juha Pyrhönen, Valéria Hrabovcová, R. Scott Semken, **"Electrical Machine Drives Control - An Introduction"**, John Wiley & Sons Ltd, 2016.*
- *Nguyen Phung Quang, Jörg-Andreas Dittrich, **"Vector Control of Three-Phase AC Machines, System Development in the Practice (2nd)"**, Springer-Verlag Berlin Heidelber, 2015.*







Grading

Attendance on hands-on lectures	0~10 %
Assignment and hands-on Exercise	40 %
Quiz	10 %
Mid-Term Project	20 %
Final Project and Report	30 %

- **Please bring your own COMPUTER to practice courses.**
- **Please check MOODLE for lecture and homework.**