METU EE462 Utilization of Electric Energy

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EE462 – Course Outline

- Basic Theory of Electromechanical Motion (~2 weeks)
- Fundamentals of Electric Machines (~1 weeks)
- DC Machine Drives (~1 weeks)
- Creating Rotating Field and Ideal Rotating Transformer (~2 weeks)
- Synchronous Machine Drives (~3.5 weeks)
- Induction Machine Drives (~3 weeks)
- Switched Reluctance Machine Drives (~1.5 weeks)

Course Info

Section 1

Tuesday: 13:40-14:30 @ D131

Thursday: 13:40-15:30 @ D131

Course Assistant

M.Sc. İlker Şahin

Office: C-114

Email: silker@metu.edu.tr

Textbooks

1. R.W. De Doncker, D.W.J. Pulle, A. Veltman: Advanced Electrical Drives, Springer Netherlands, 1st Edition, 2011.
2. A. Hughes, Electric Motors and Drives: Fundamentals, Types and Applications, 4th Edition, Newnes, 2013.
3. W. Leonhard: Control of Electrical Drives, Springer Verlag Berlin Heidelberg, 3rd Edition 2001.
4. Mohan N., Undeland T., and Robbins W., “Power Electronics: Converters, Applications, and Design”, John Wiley & Sons, 2002.

Laboratory Work

- Fan Load Driven by Variable Frequency Drive (VFD)
- Variable Frequency Drive (VFD) Driven Crane Hoist with Speed Feedback
- Centrifugal Pump Load Driven by Variable Frequency Drive (VFD)
- (Demo) Hardware in the loop Motor Drive Controller
- (Demo) Light Rail Vehicle Traction System

NEW!

Grading

- 1 midterm examination, 25%
- 1 final examination, 35%
- Project (report and presentation), 20%
- Laboratory: 20%

Course & Instructor Policies

- Class attendance will be taken but will not be graded.
- Late assignments are not allowed unless the reason is stated and approved in advance.
- Any of the following actions will result in NA grade:
  - Not submitting the term project
  - Not attending to the final exam
  - Not attending to any of lab sessions

What is the best way of learning?

Lectures are good to get familiar and also learn the most important aspects.

+

Books include consistent content and good to build a complete understanding.

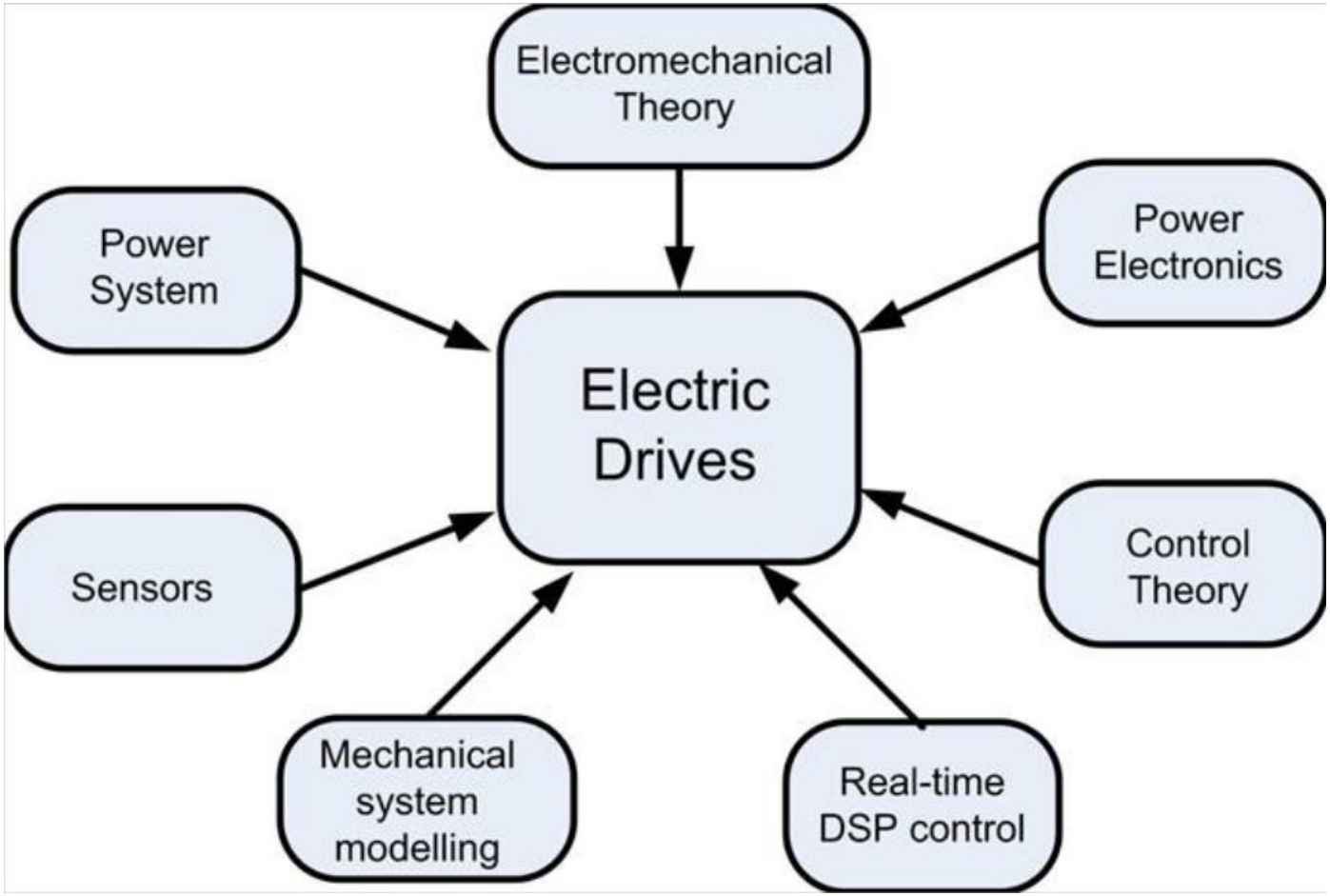
+

Our brains are lazy, **exercises** makes us think deeply and crucial to see what is understood what was assumed to be understood.

+

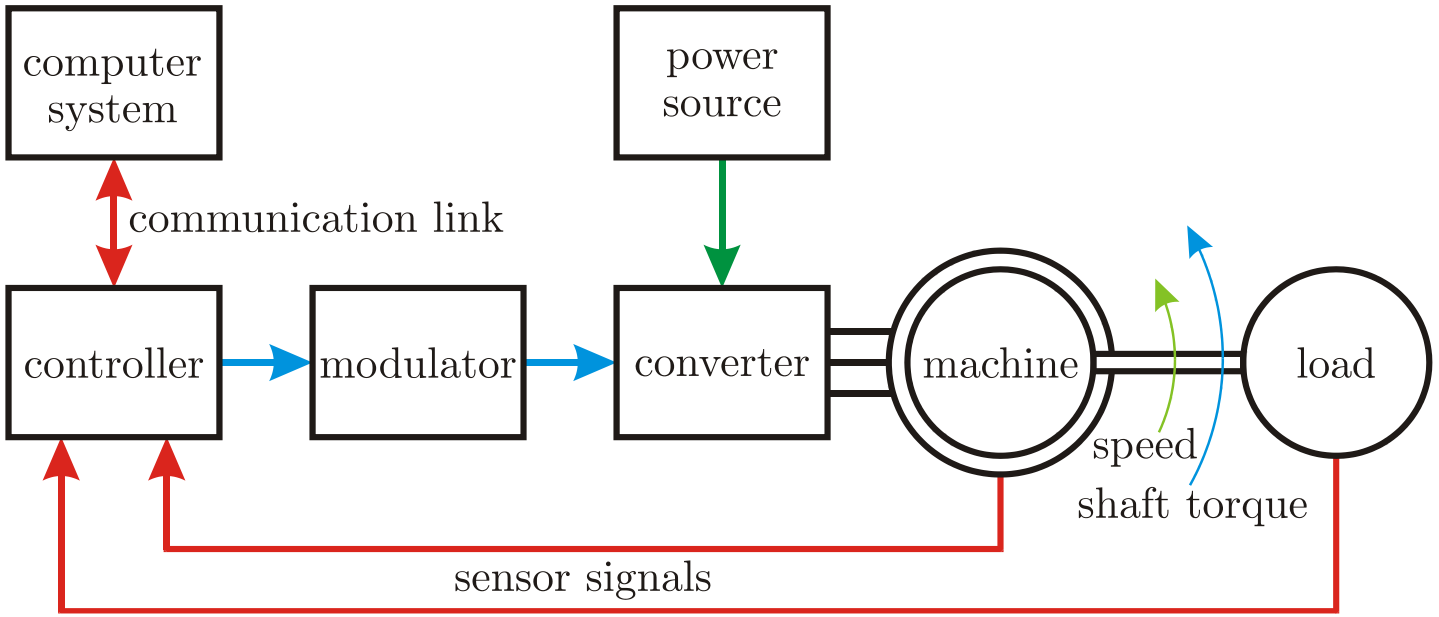
Projects are means of being totally involved in the content by activing our creativity and problem solving skills.

Multi-Disciplinary Nature of Electric Drives



Electric Drive: Motion Control Systems

A Typical Drive Set-up



An **electric machine** (motor and generator) to convert electric energy into mechanical energy or vice versa.
A **power converter** which supplies voltages and currents needed by the machine by amplifying control signals.
A **controller** that generates control signals using predefined (or self leaning capability) algorithms and sensed values like voltage, current, position, speed, frequency to guarantee the desired energy conversion process.

Challenges

Mechanical Design

Electromagnetic Design

Volume Limits

Power Electronics

Cost Limits

System Efficiency

Safety Critical Applications

Control

Losses – Thermal Behavior

Material Selection

Mass Limits

Cooling Design

Component Selection

Milestones in Development of Electric Drives

1. Invention of Electric Machines - starts around 1820s

   In 1821 Michael **Faraday** (British) creates two experiments for the demonstration of electromagnetic rotation.

   In 1887 **Tesla** files his first patents for a two phase AC system with four electric power lines, which consists of a generator, a transmission system and a multiphase motor.

2. Development of Power Electric Converters – Voltage, Current, Frequency Control – starts around 1960s

   1952: Power diode
   1957: Thyristor
   1960s: Bipolar transistor
   1970s: MOSFETs
   1980s: IGBTs

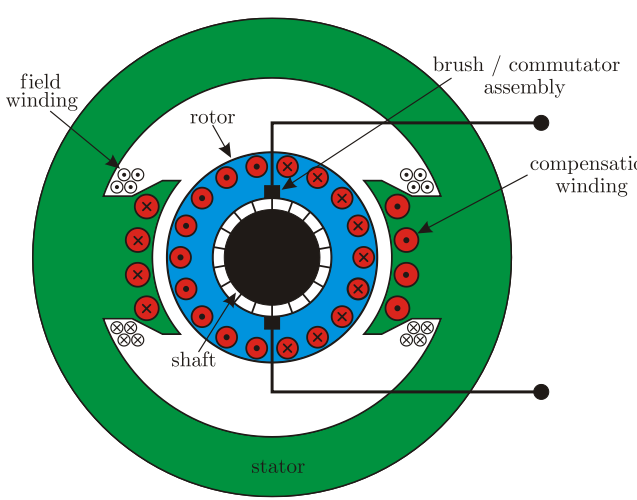
3. Development of Control Algorithms – starts around 1980

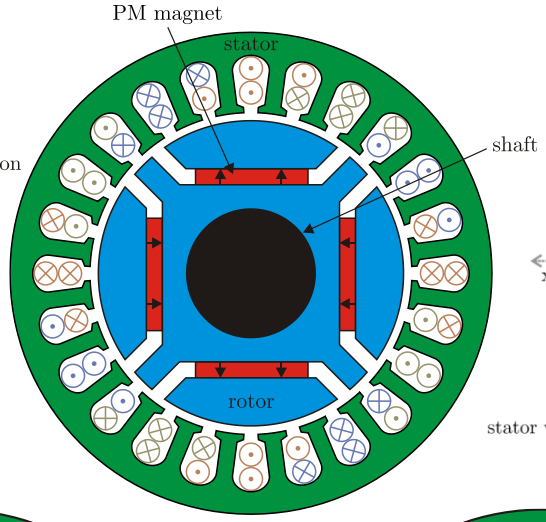
   1980s: Invention of Field Oriented Control

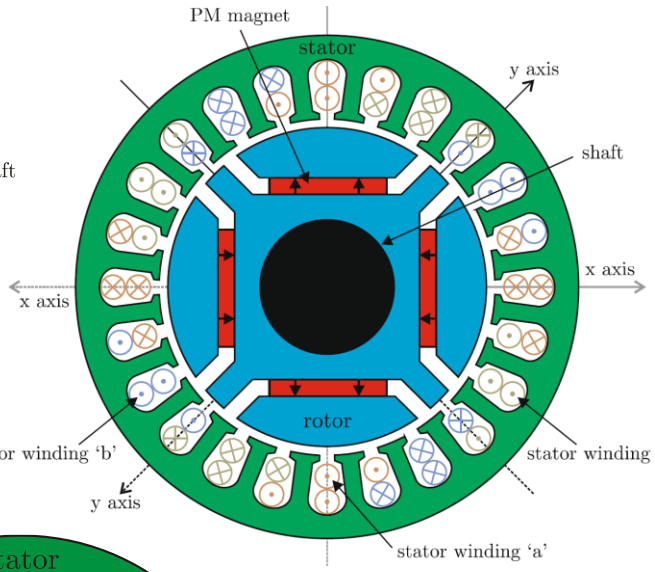
4. DSPs and Microcontrollers – starts around 1980

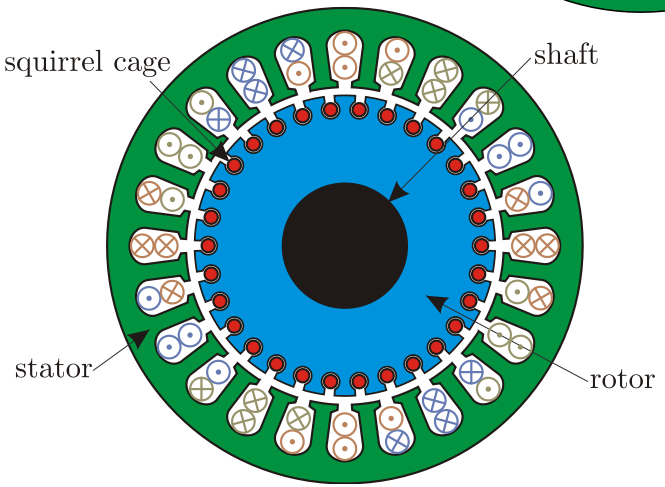
   1982: First DSP

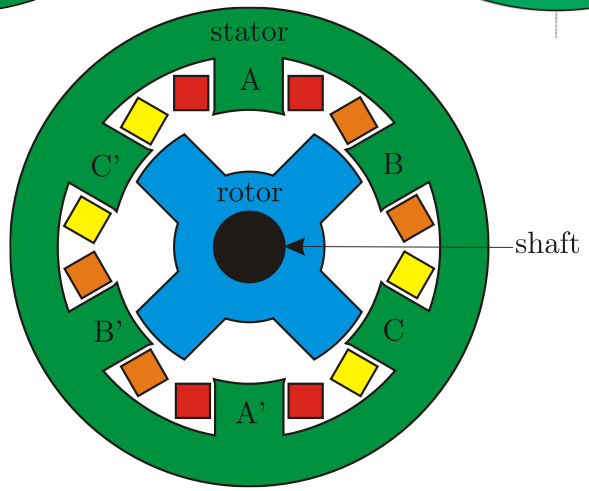
Typical Machine Types







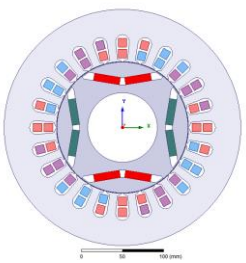


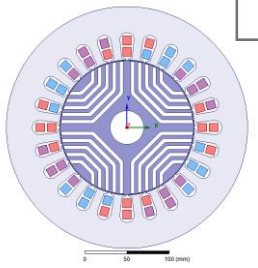


Can you distinguish the types of the machines above?

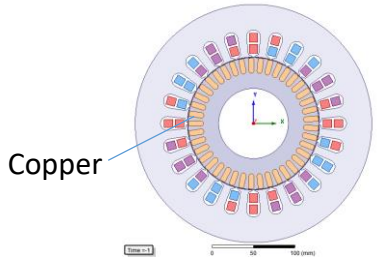
Typical Machine Types

- Stationary Field
  - DC-Machines
    - PM-excited
    - Electrically excited
- Rotating Field
  - Synchronous
    - Radial flux
      - Stator with rotating field winding
        - PM-excited
          - Trapezoidal excitation
          - Sinusoidal excitation
        - Electrically excited
        - Salient pole

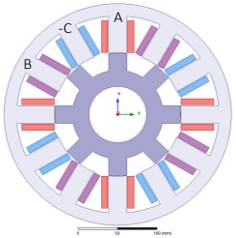




      - Modular windings
        - PM-excited
        - Electrically excited



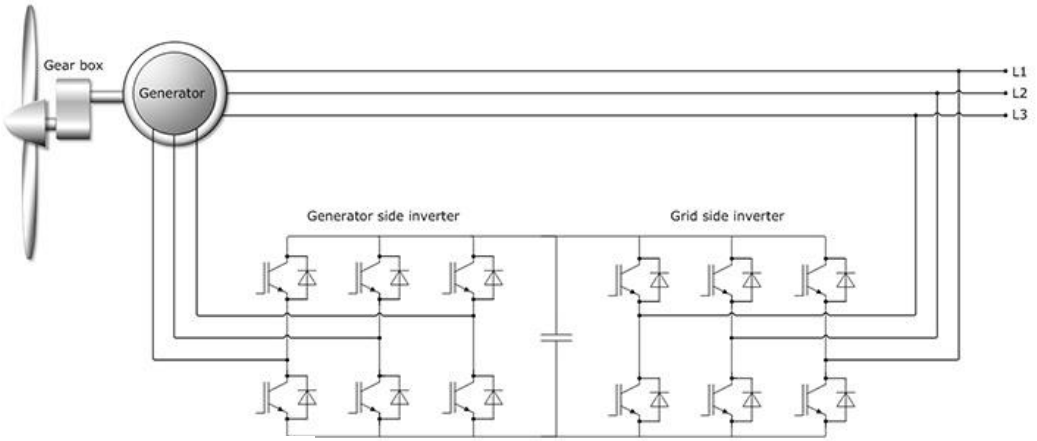
    - Axial flux
    - Transversal flux
  - Asynchronous
    - Rotor with slip rings
    - Squirrel-cage rotor
- Switched field
  - Salient pole

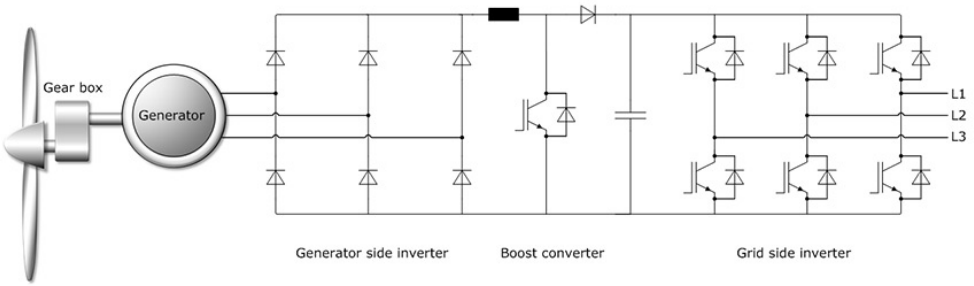


Electrical Drive System Examples

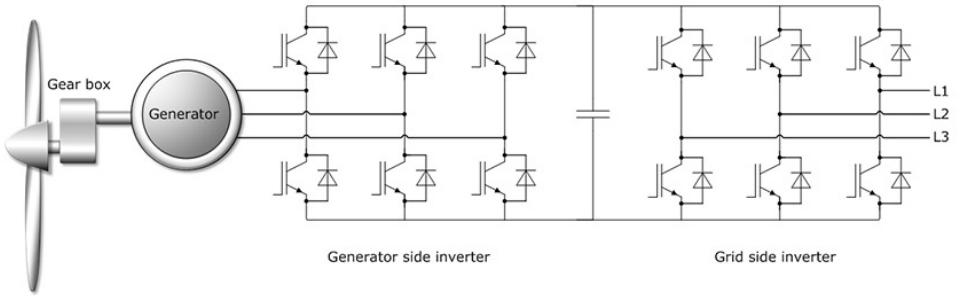
Wind Energy

Block diagram of a wind turbine with doubly-fed induction generator - 80 per cent of regulated wind turbines installed





Block diagram of a wind turbine with 2-quadrant inverter



Block diagram of a wind turbine with 4-quadrant inverter

https://www.semikron.com/applications/wind-energy/application-examples.html

Electrical Drive System Examples

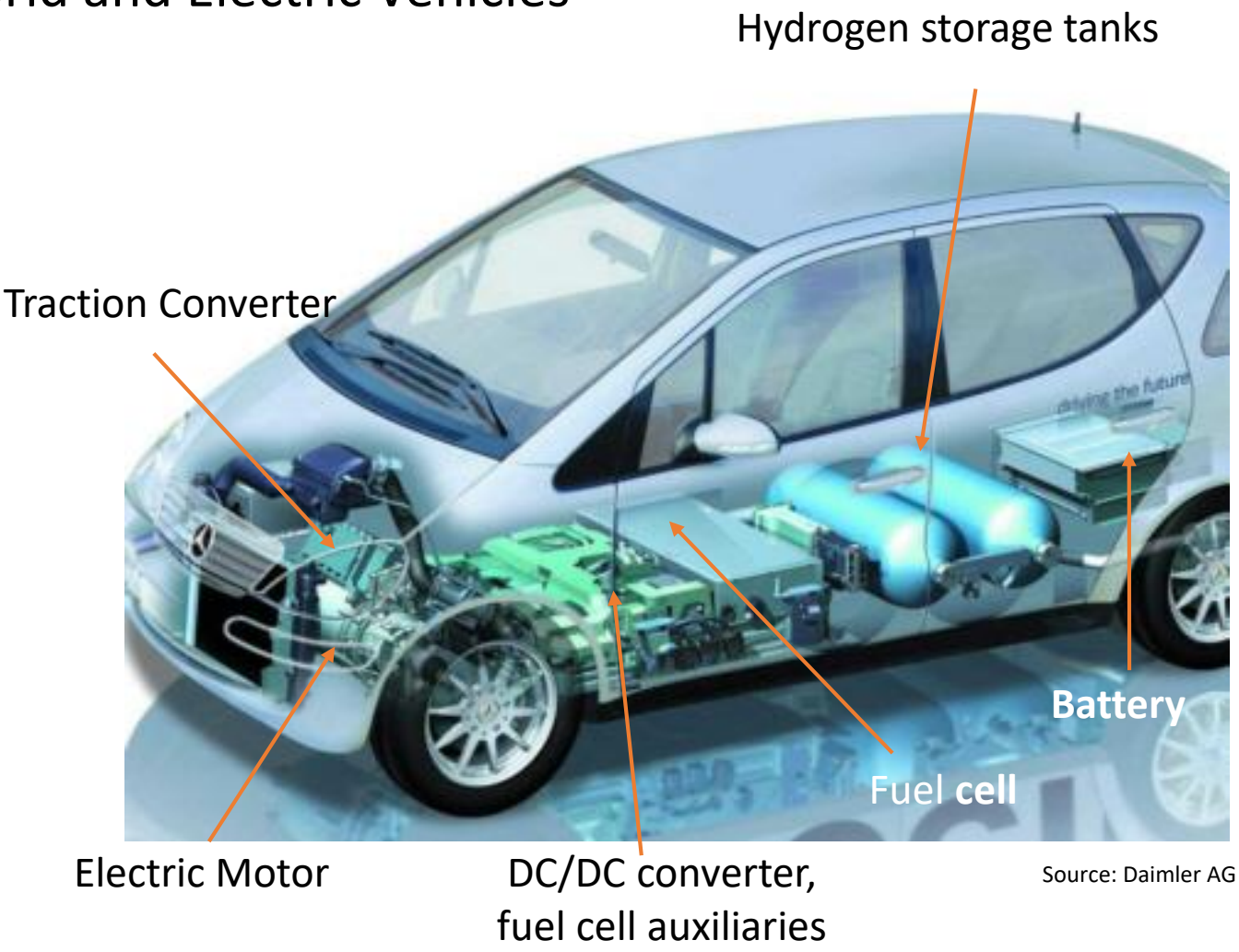
Hybrid and Electric Vehicles

The car I was testing at VW


Toyota's Fuel Cell Vehicle

Electrical Drive System Examples

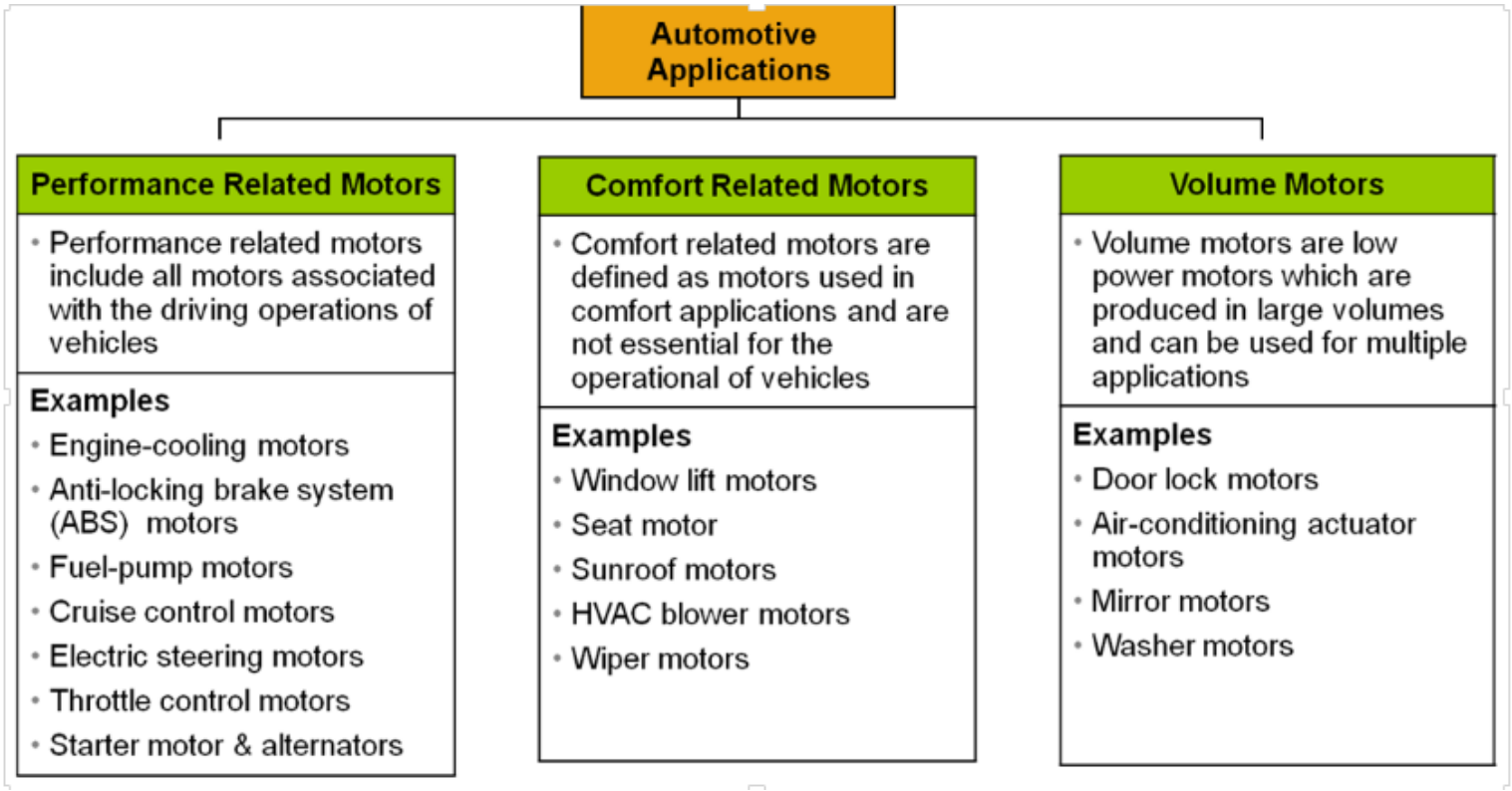
Hybrid and Electric Vehicles



Source: Daimler AG

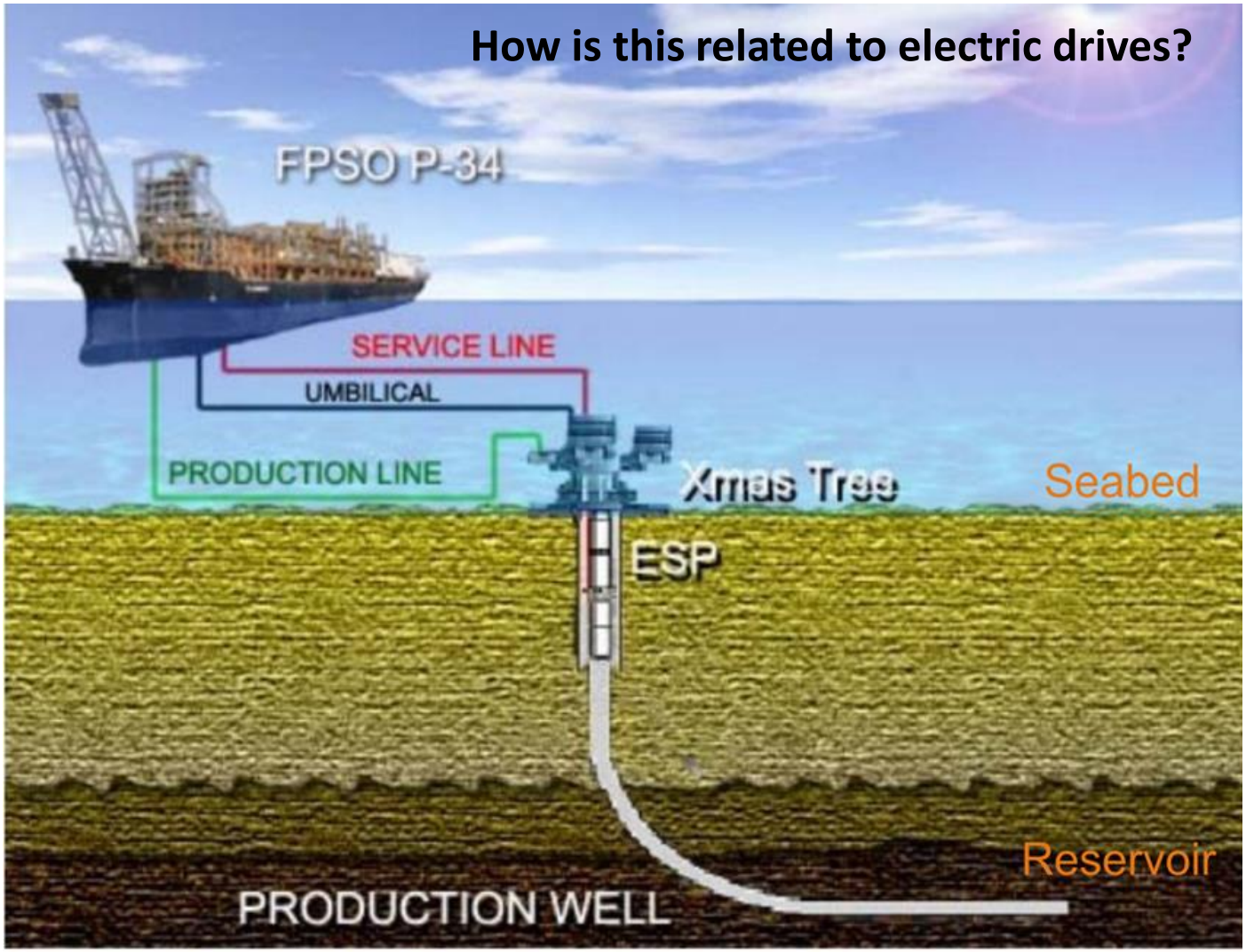
Electrical Drive System Examples

Electric Machines in a Regular Car



https://etn-demeter.eu/how-many-electric-motors-are-in-a-car/

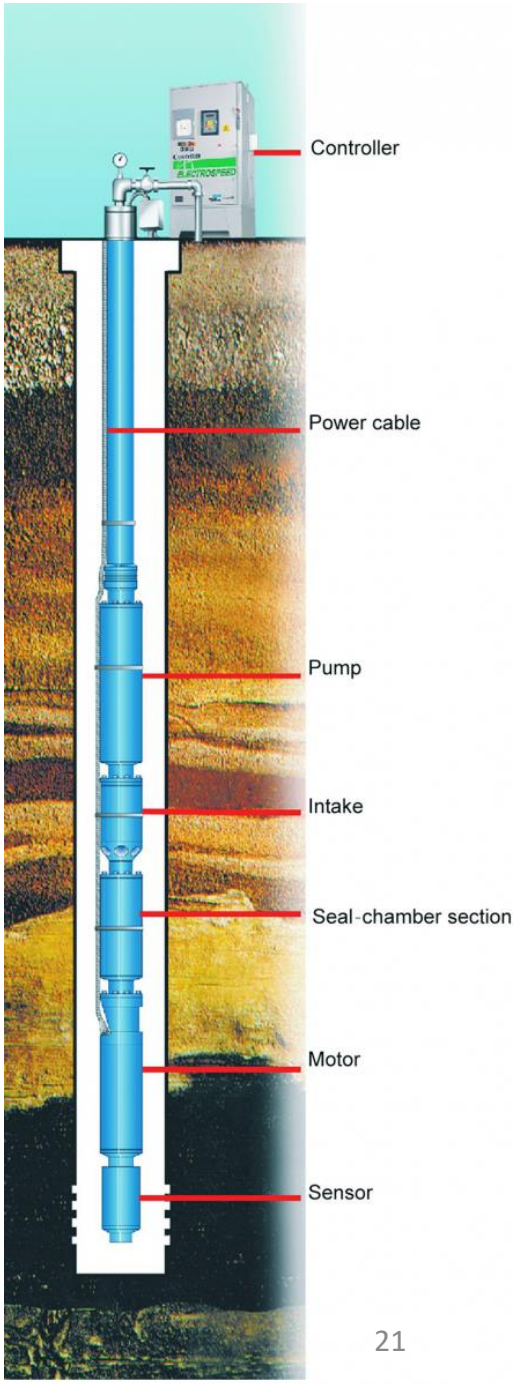
Electrical Drive System Examples



Electrical Drive System Examples

Variable speed drives (VSDs) for electrical submersible pumps (ESPs)

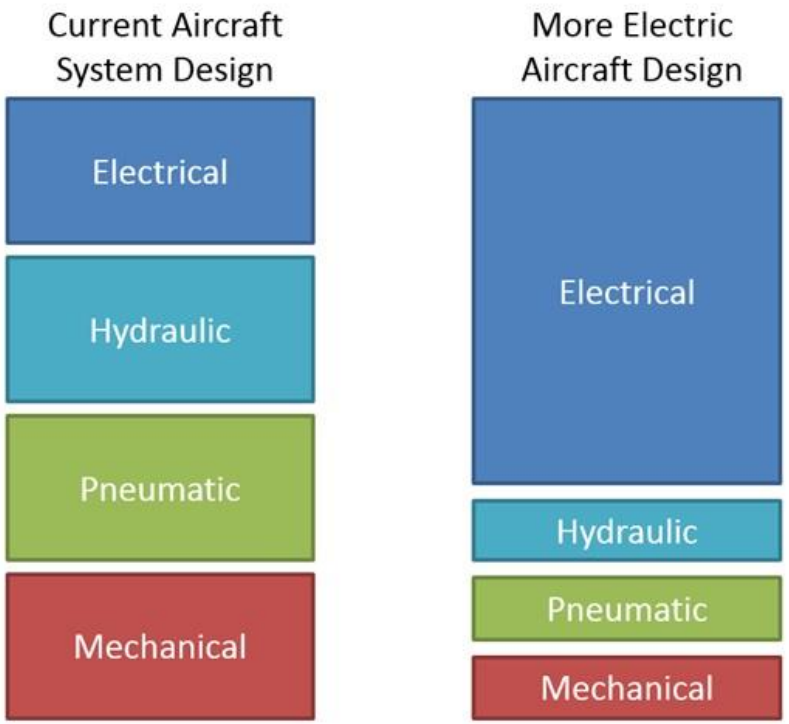
The electrical submersible pump, typically called an ESP, is an efficient and reliable artificial-lift method for lifting moderate to high volumes of fluids from wellbores.

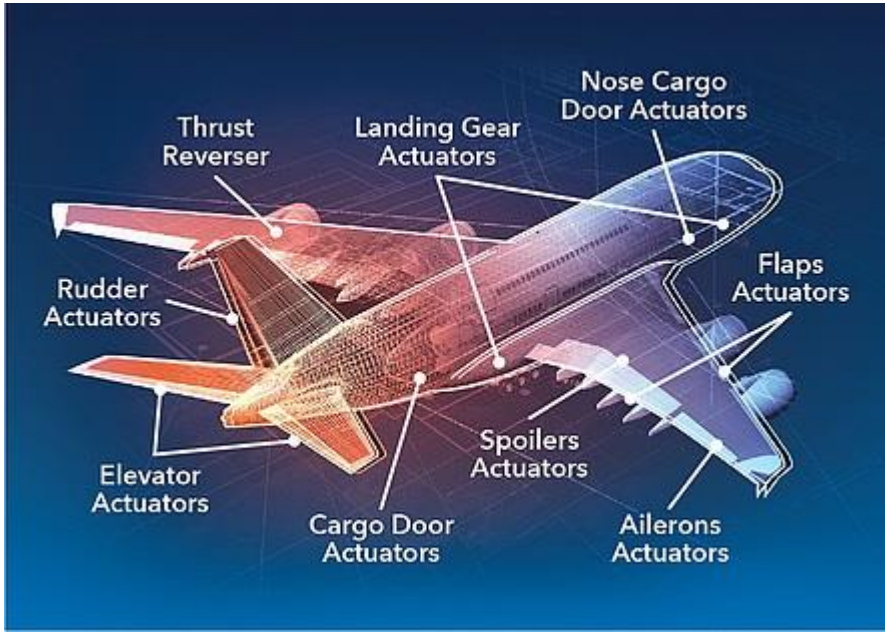


https://petrowiki.org/Electrical_submersible_pumps

Electrical Drive System Examples

More Electric Aircraft





What are your expectations from this course?

A. To get a passing grade to finish power electronics area must courses and graduate.

B. Combine my electric machine and power electronics knowledge to understand motion control systems.

C. To be able to talk about a wind turbine when we see one on the way to my holiday location.

D. To understand the functions like regenerative breaking and components in electric and hybrid electric vehicles.

E. All of above.

Assignment: Please take some time to think on your expectations from EE462, which gap is it going to fill in your engineering knowledge?

References and interesting links:

History of electric machines:
https://www.princeton.edu/ssp/joseph-henry-project/electric-motor/electric-motor-history.pdf

Feynman on Electric Machines

Volkswagen Fuel Cell EV:

https://www.youtube.com/watch?v=gQZj5PiOwv8

Advertisement:

https://www.youtube.com/watch?v=13bG9xnoMSQ