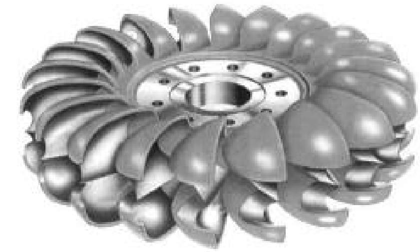
Machines électriques

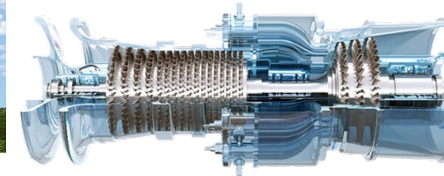
Introduction

André Hodder

v8

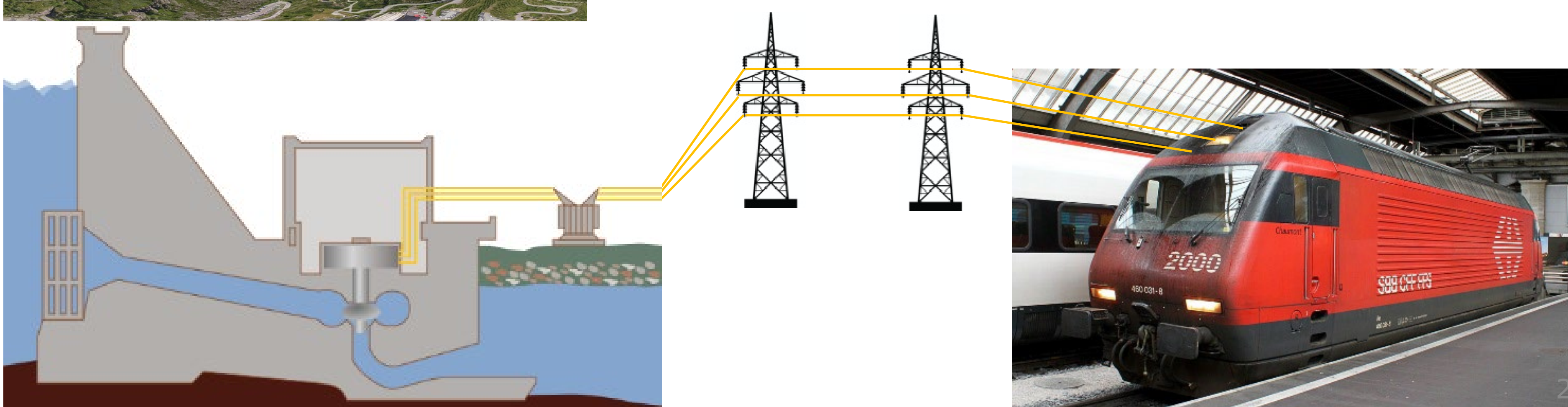
Conversion électromécanique





Electrique — Moteur → / ← Génératrice — Mécanique

Pourquoi l'énergie électrique ?



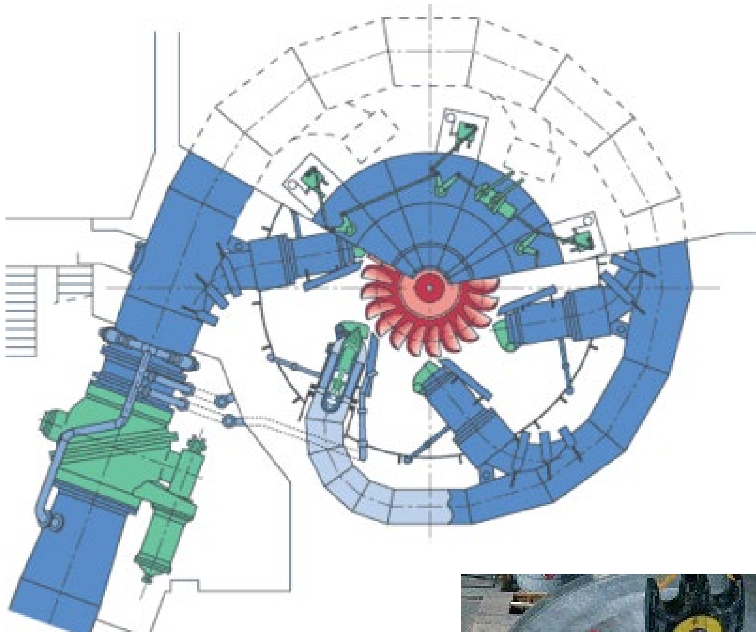
Production d'énergie électrique

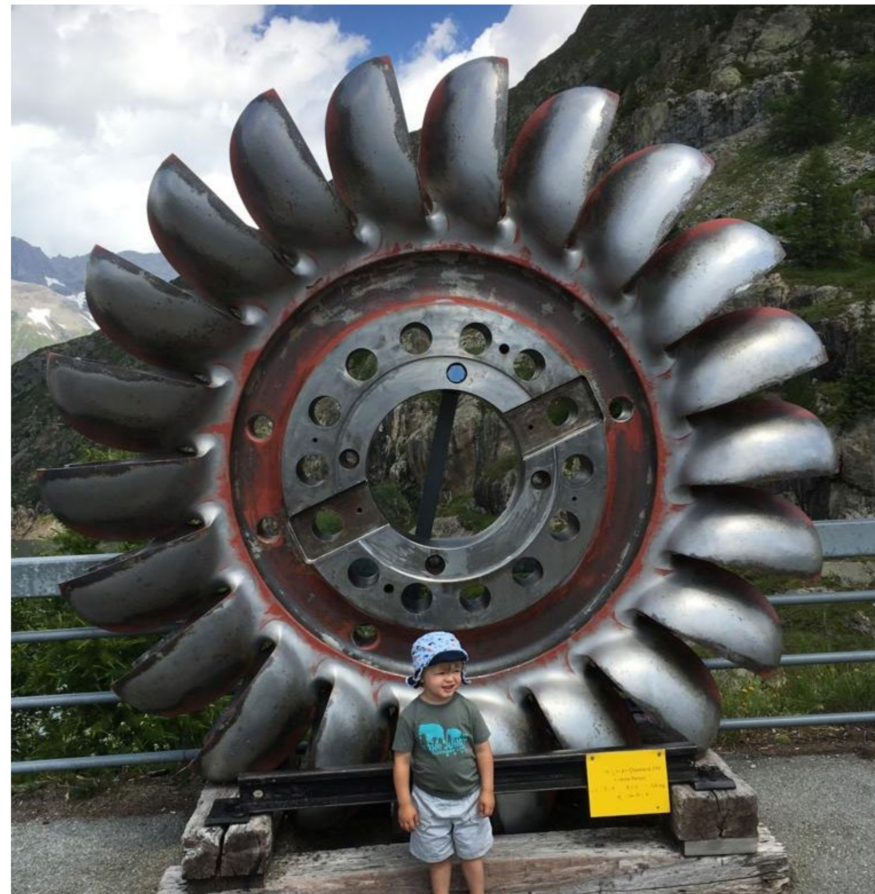
Source :
wikipedia
panoramik.ch

Production d'énergie électrique - Hydro

Phase de conversion finale pour la production d'énergie électrique

- Electromécanique
- Puissances typiques: 0.5 – 500 MW





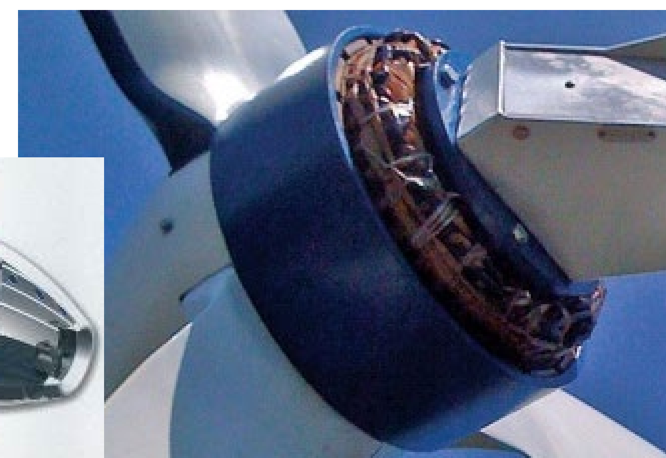
Source : wikipedia

Production d'énergie électrique - Eolien

Source :
wikipedia
blog.bkw.ch
www.rjb.ch

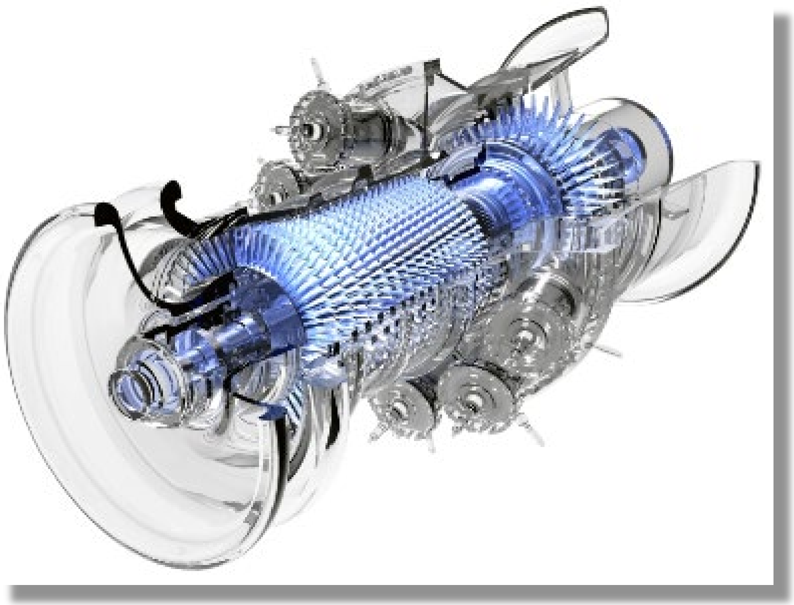
Phase de conversion finale pour la production d'énergie électrique

- Electromécanique
- Puissances typiques: 0.1 – 6 MW



Production d'énergie électrique
Cycles thermiques

Cycles gaz (Brayton)



Cycles basés sur la vapeur

- charbon
- pétrole
- cycles combinés (gaz-vapeur)
- combustibles nucléaires

Phase de conversion finale pour la production d’énergie électrique

- Electromécanique
- Puissances typiques:
  0.1 – 200 MW

Phase de conversion finale pour la production d’énergie électrique

- Electromécanique
- Puissances typiques:
  10 – 500 MW

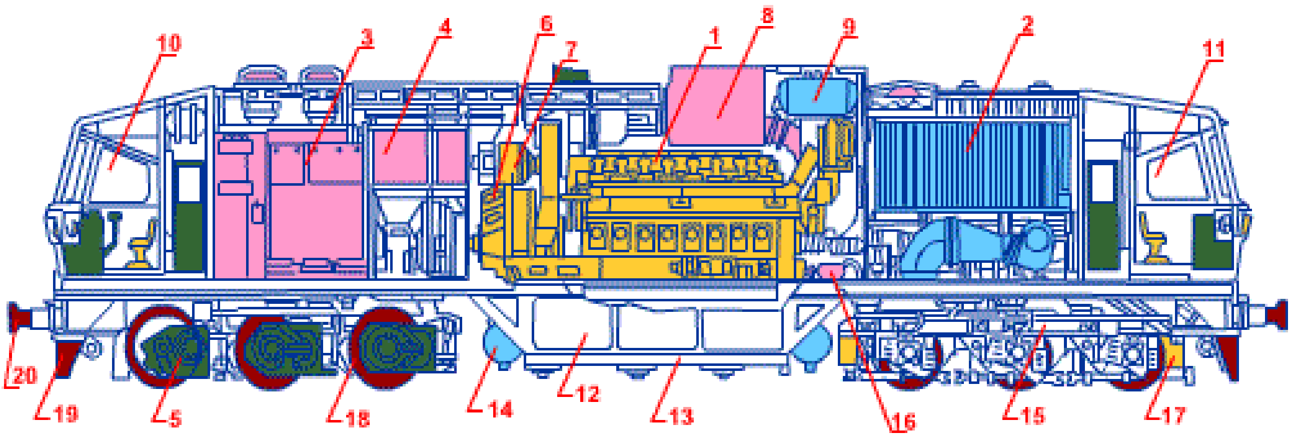
Traction ferroviaire

Locomotive électrique

Puissance (totale) : 6 MW
4 moteurs asynchones

Locomotive Diesel-électrique

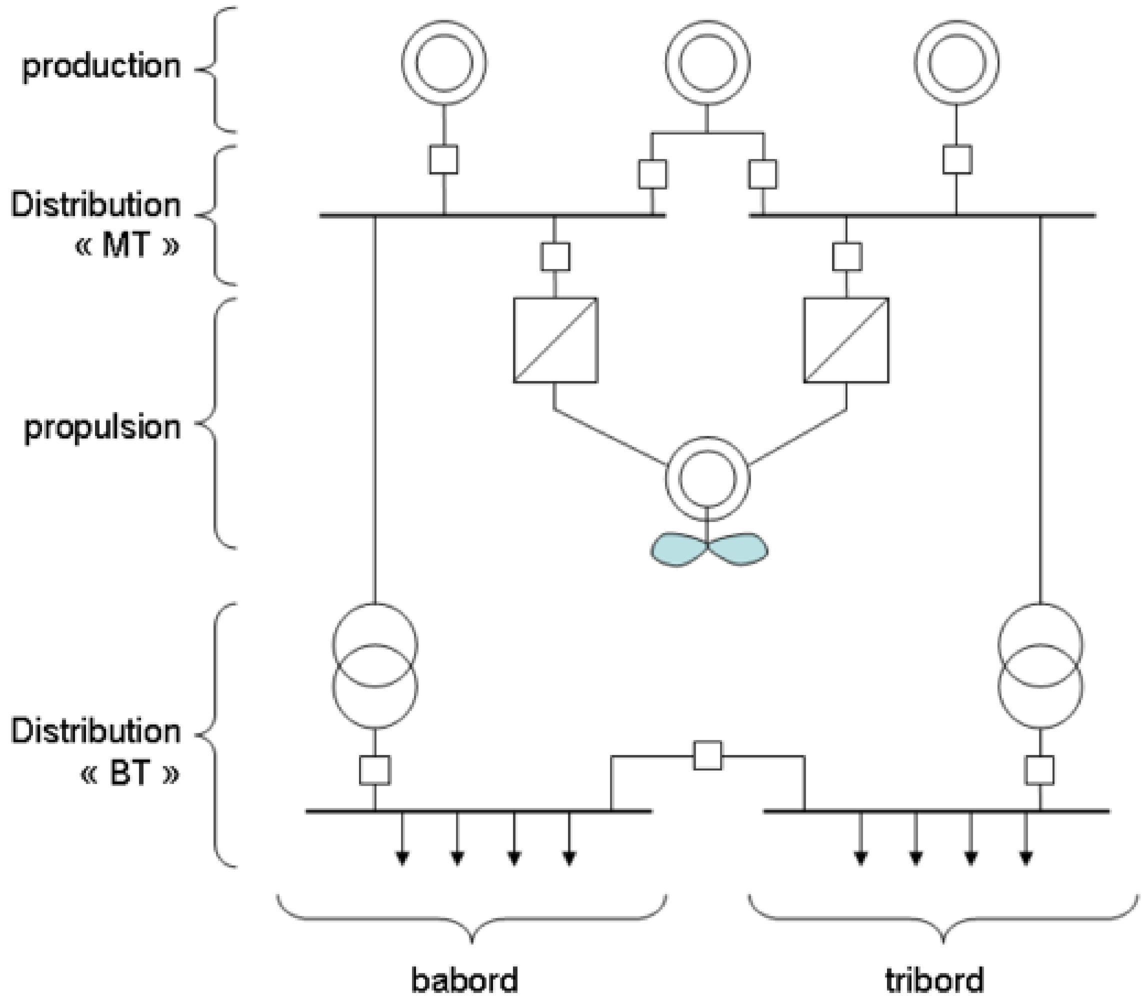
Puissance (totale) : 4.8 MW
2 moteur diesel



1 — Moteur Diesel
5 — Moteur électrique de traction
6 — Générateur

Source : wikipedia

Propulsion électrique dans la marine



Source : wikipedia

Vibreur de téléphone

Source :
quora.com
imore.com

LILIUM

Source :
lilium.com

Source : h55.ch

Source :
tesla.com
largus.fr
carvolution.com
peugeot.ch

phonandroid.com/vw-id-3-volkswagen-moteur-electrique-si-petit-tient-dans-...

VW ID.3 : Volkswagen présente son moteur électrique si petit qu'il tient dans un sac

PAR DAVID IGUE, 15/11/2019

PARTAGER TWEETER PARTAGER ENVOYER À UN AMI 14 COM'S

La VW ID.3 arrive au printemps 2020 et la production vient tout juste de démarrer, l'occasion pour Volswagen de dévoiler le moteur électrique qu'embarquera le véhicule. Bien qu'il délivre une puissance brute de 200 chevaux, ce moteur est si minuscule qu'on pourrait le mettre sans difficulté dans un petit sac de sport. Le gabarit est impressionnant comparé à l'envergure des moteurs thermiques.

Platforme MEB

Electric motors [edit]

Rear axle [edit]

APP 310 [edit] 204 ch

The MEB platform is supported by the APP 310 electric motor, which is a permanent magnet brushless motor. Fully developed by Volkswagen, the name "APP" derives from the arrangement of the motor and the gearbox in parallel with the axle, while "310" references its maximum torque of 310 N·m (31.6 kg·m; 229 lb·ft). Maximum torque is achieved at a low engine speed, which means that a 1-speed gearbox is sufficient for the entire rotational speed range. Together with the gearbox, the motor weighs only around 90 kg (200 lb).[43]

The motor is produced at component sites in Kassel, Germany and Tianjin, China, while the rotor and stator are produced in Italy by Eurotranciatura S.p.a..

APP 550 [edit] 286 ch

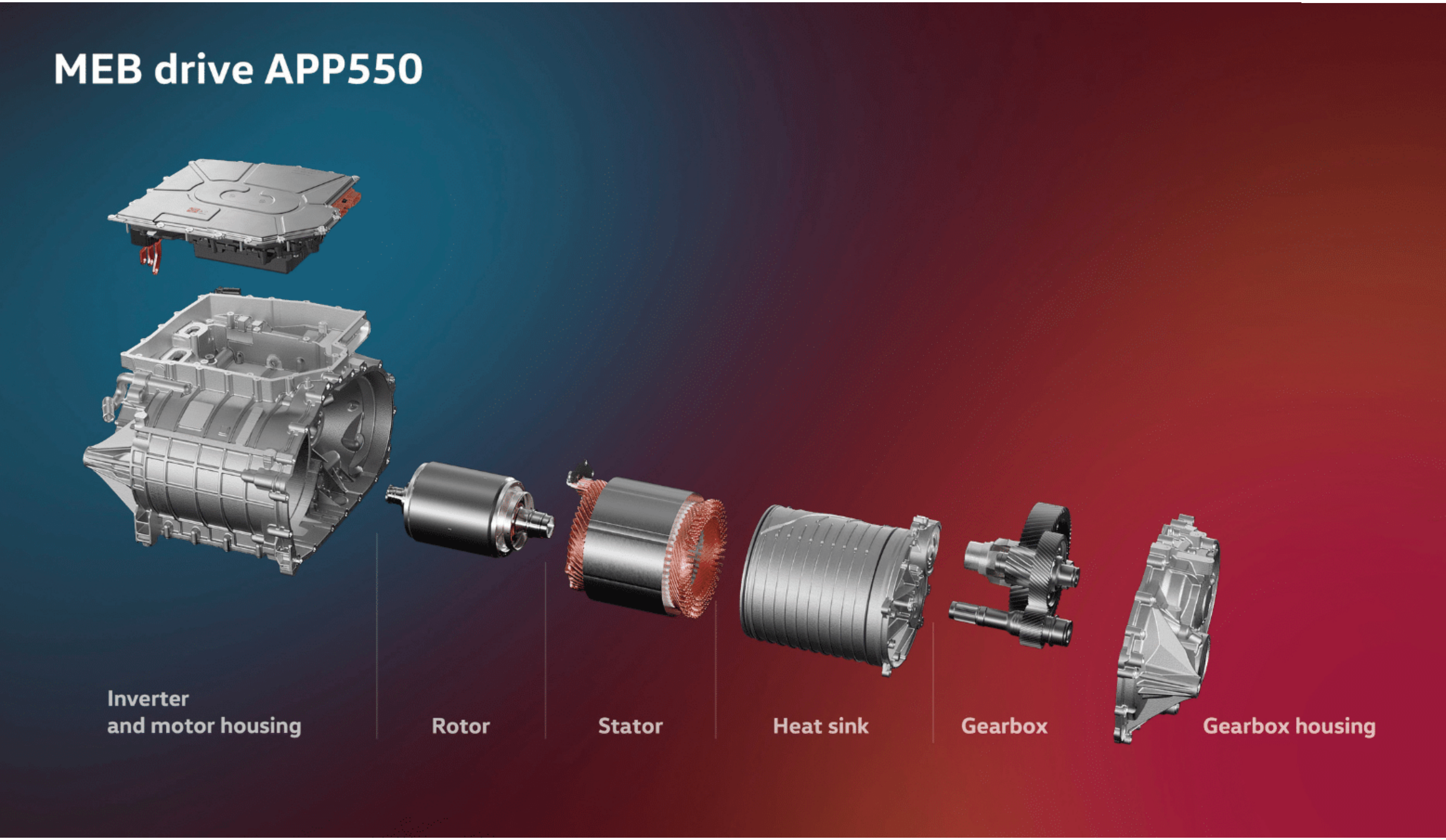
The APP 550 was unveiled in April 2023 and delivers 550 N·m (56.1 kg·m; 406 lb·ft), as the naming scheme suggests. It is the same size as the APP 310. According to a press release the efficiency has been increased through an improved inverter.[44]

Optional Front axle [edit]

All-wheel drive models are equipped with an auxiliary front axle motor. This motor is a 3-phase AC induction motor. It is only used when needed for acceleration or handling. It is purchased from a Magna subsidiary.[45]

https://en.wikipedia.org/wiki/Volkswagen_Group_MEB_platform

APP550



https://www.automobile-propre.com/articles/app550-le-moteur-electrique-volkswagen-qui-va-tout-changer/

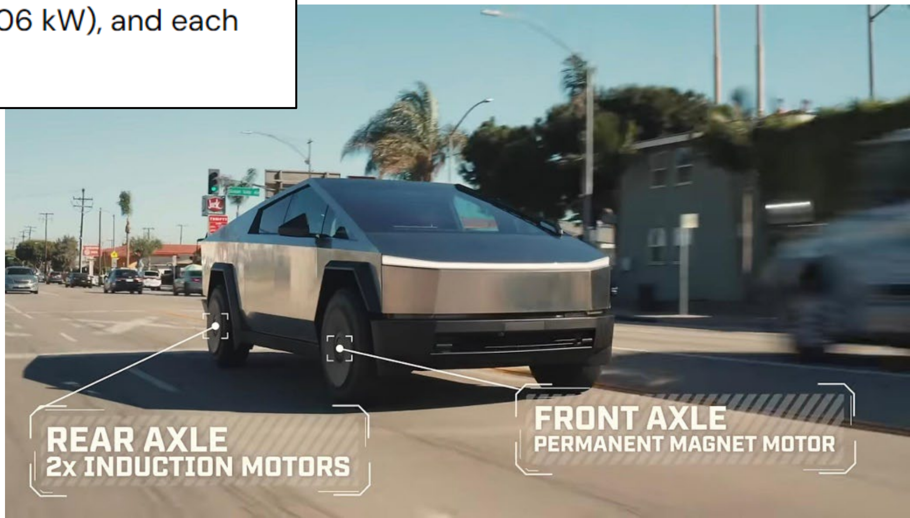
Three Motor Configurations Of Cybertruck

The Cybertruck offers three configurations: tri-motor all-wheel drive (AWD), dual-motor AWD, and single-motor rear-wheel drive (RWD).

Single Motor: A permanent magnet motor is mounted on the rear axle, providing rear-wheel drive.

Dual Motor: The front axle is equipped with an induction motor, and the rear axle has a permanent magnet synchronous motor, achieving all-wheel drive. The front induction motor produces a maximum power output of 303 horsepower (226 kW), while the rear permanent magnet motor delivers 297 horsepower (221 kW), with a total output of 600 horsepower (450 kW).

Tri-Motor: Two induction motors are installed on the rear axle, and a permanent magnet synchronous motor is on the front axle. This configuration provides higher power and performance. The tri-motor AWD version, known as the "Cyberbeast," delivers 845 horsepower (630 kW). The front motor produces 276 horsepower (206 kW), and each rear motor produces 284 horsepower (212 kW).



https://lammotor.com/tesla-cybertruck-motor/

EPFLoop


HYPERLOOP
POD COMPETITION
EPFLOOP
COMSOL
logitech

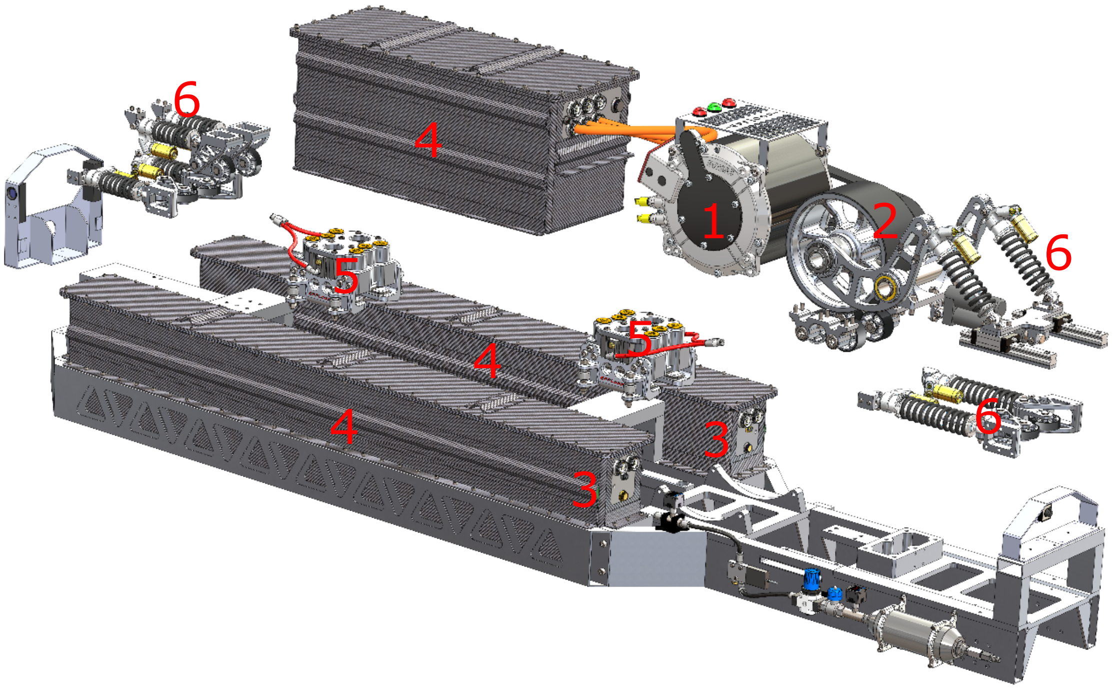

EPFL
BOBST


EPFL

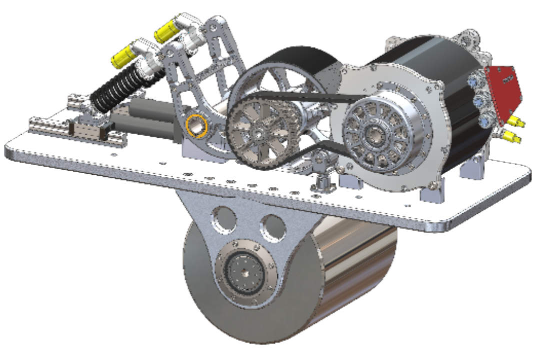
EPFLoop Pod - 2018

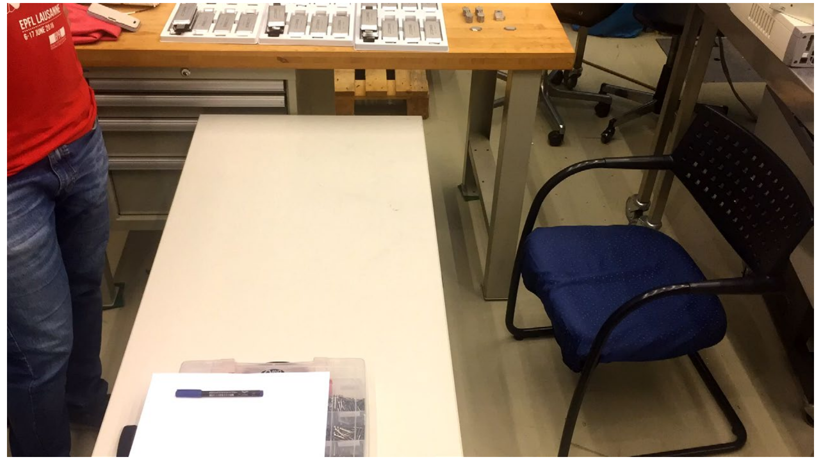
- Weight 300 kg

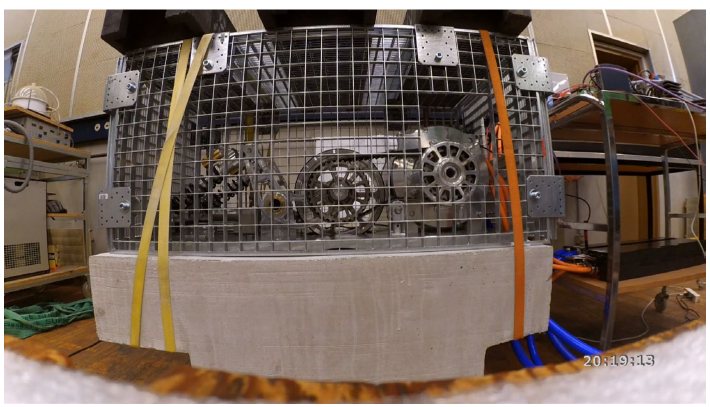
1. Propulsion e-motor (215 kW - 385 Nm)
2. Propulsion wheel (1.2g acceleration)
3. Battery (460V 600A)
4. Electronics, power electronics and battery in pressure vessels
5. Brakes (2.5g)
   - Regenerative (~0.5g)
6. Suspension system (stability) horizontal and vertical



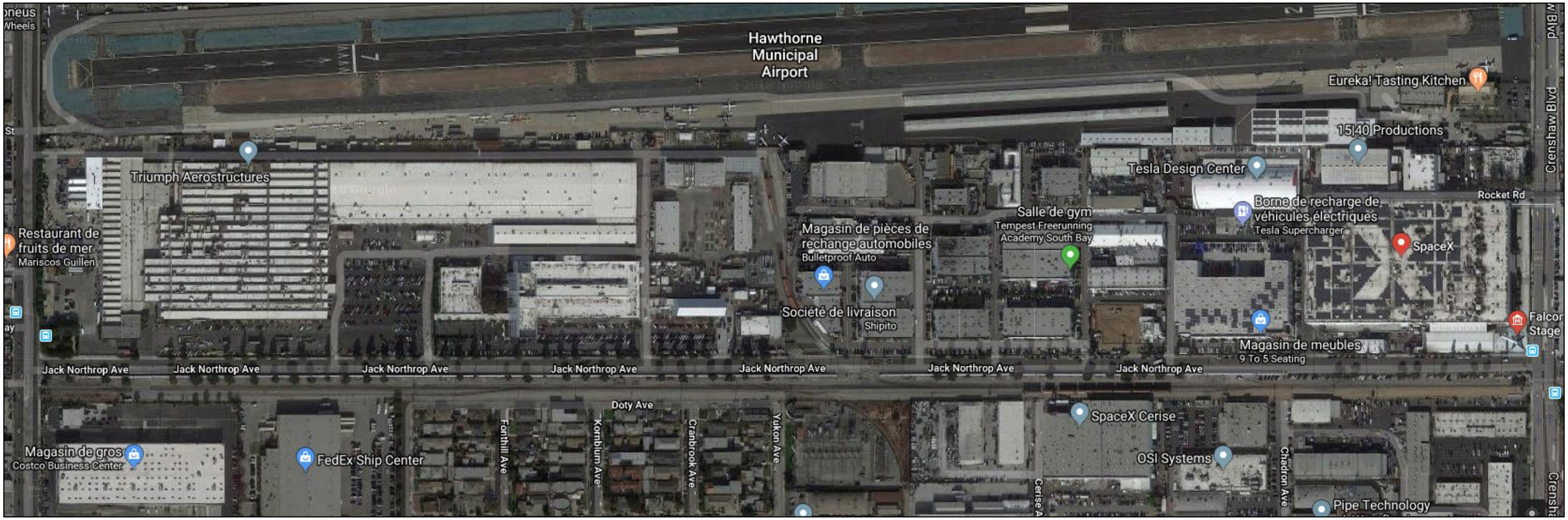
Test Facilities and Benches





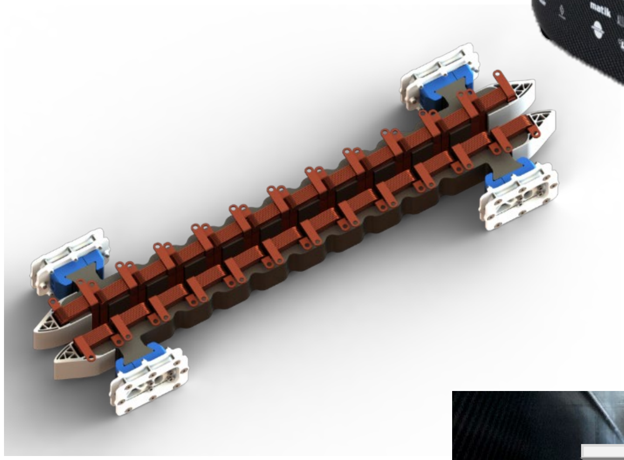


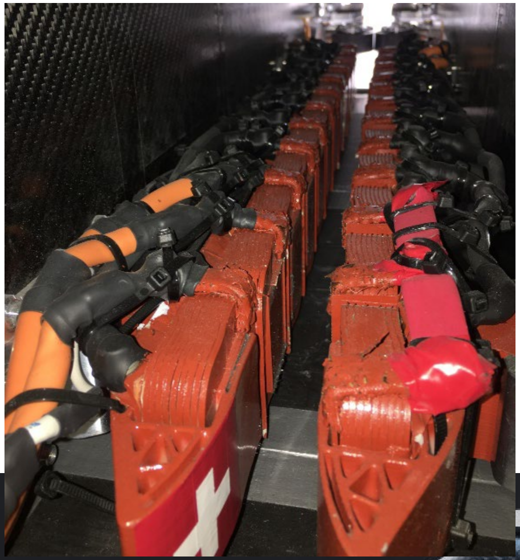
Competitions in Los Angeles



EPFLoop Pod - 2019

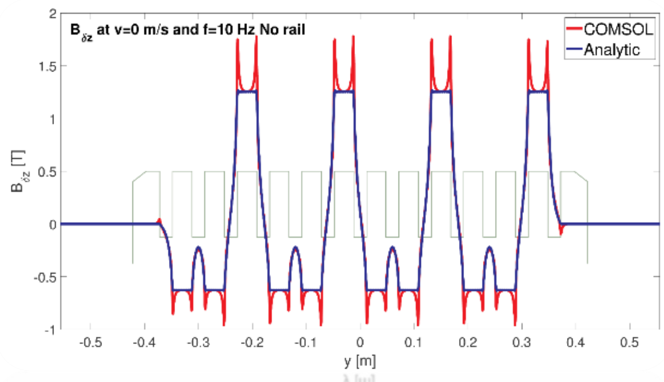
- What's new ?
  - Weight 165 kg
  - Braking at 7g
  - Linear Motor !

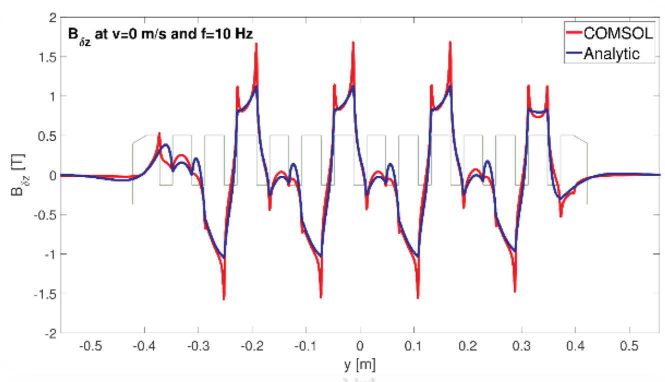




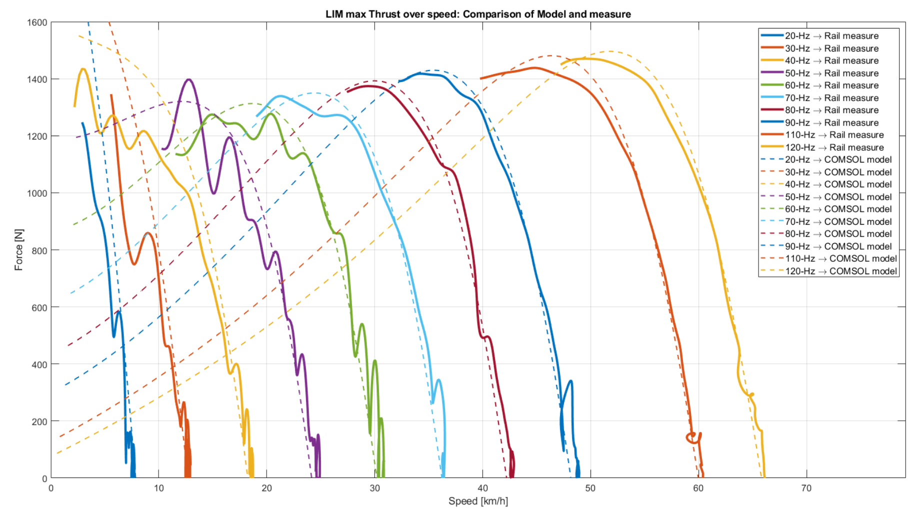
Linear Induction Motor

- 2D analytical model on Matlab
  2D multi-physics model on COMSOL

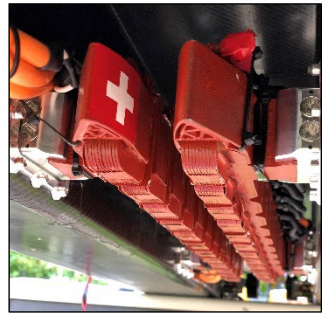




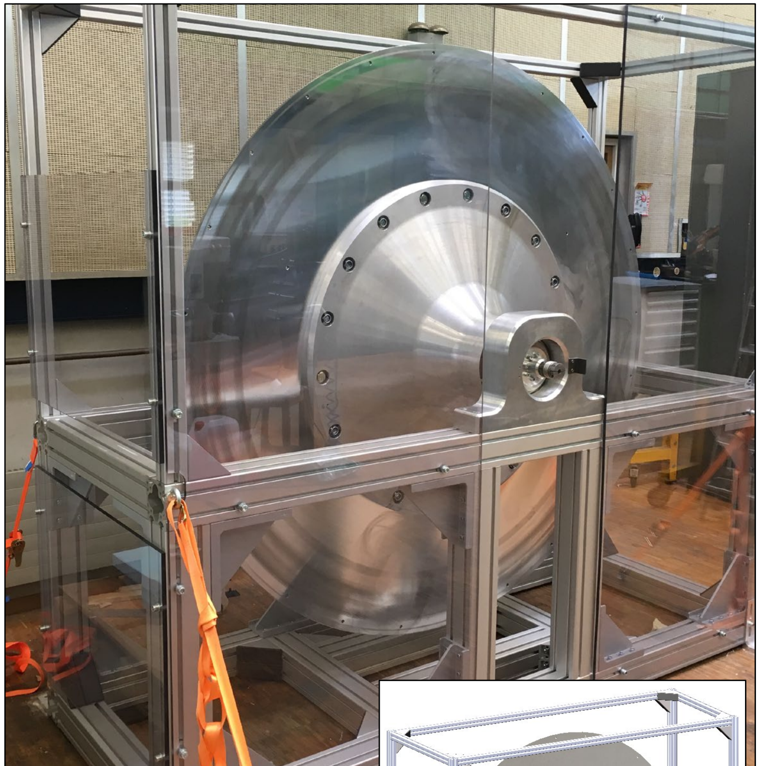
- Comparison between measurements and COMSOL simulations

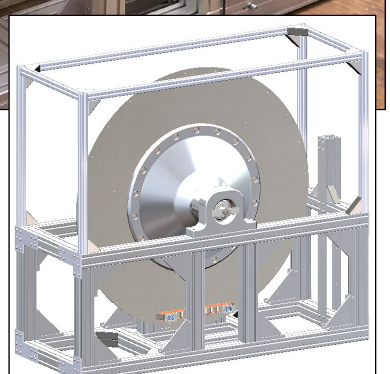


Test Facilities and Benches



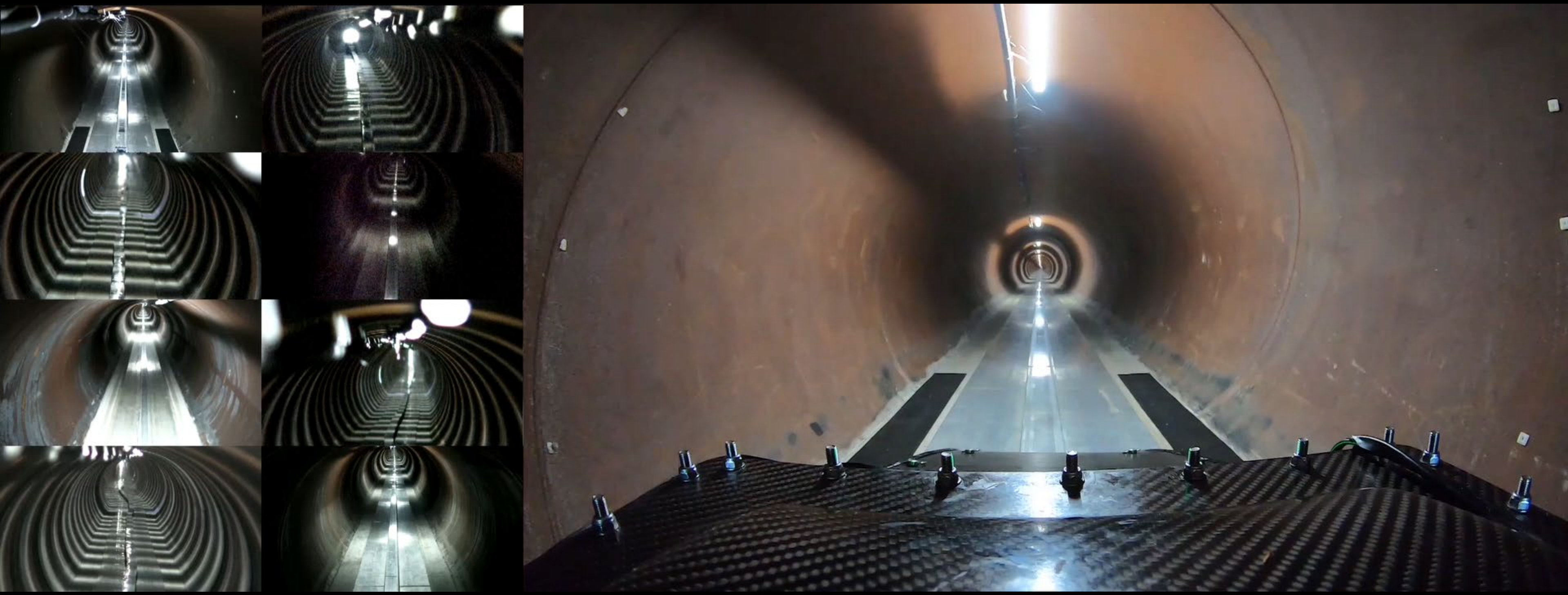
- Propulsion bench
  - Wheel of 2.1m in aluminium





- Rail of 110m

2019 Competition day

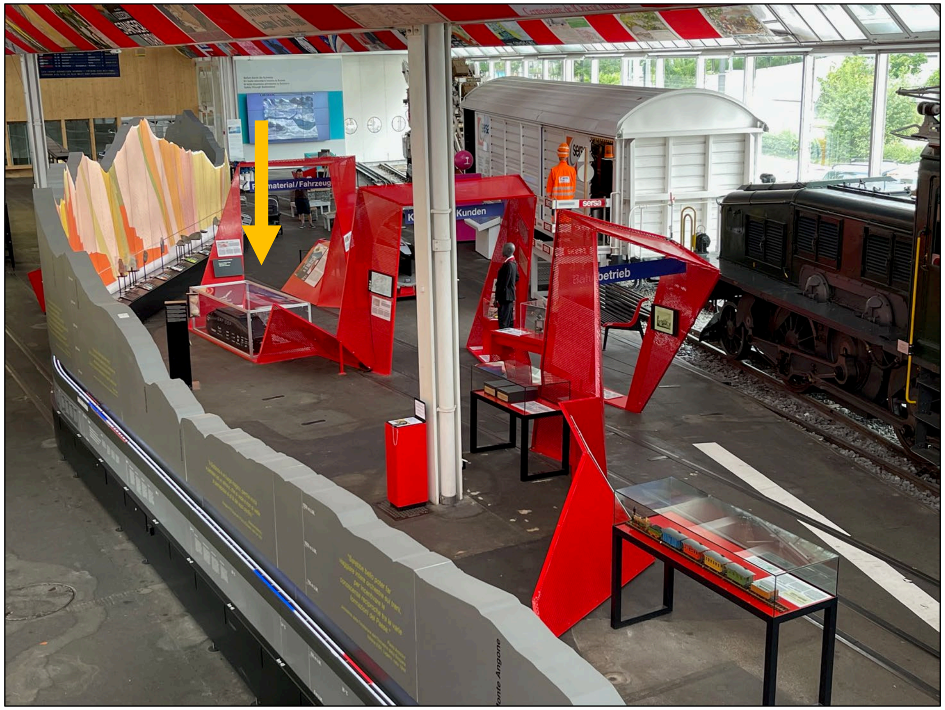


EPF|OOP


2018
EPF|OOP
COMSOL

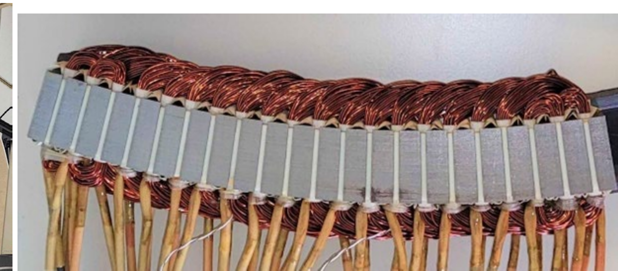

2019
PILATUS
EPF|OOP
BOBST
EPFL

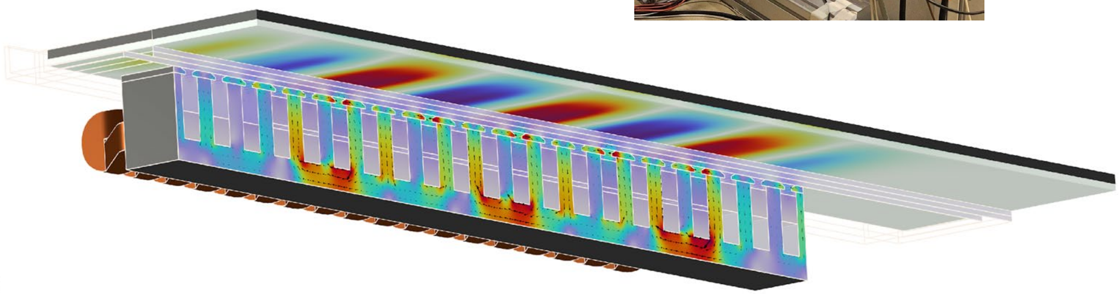

EPF|OOP
BOBST
COMSOL

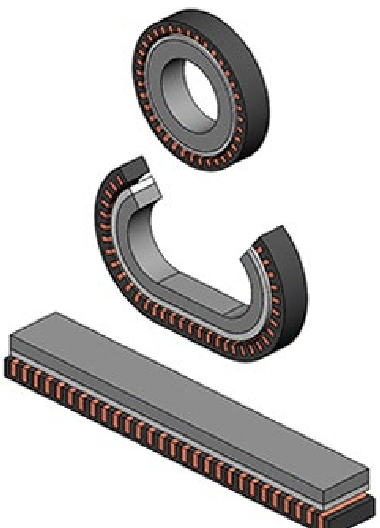


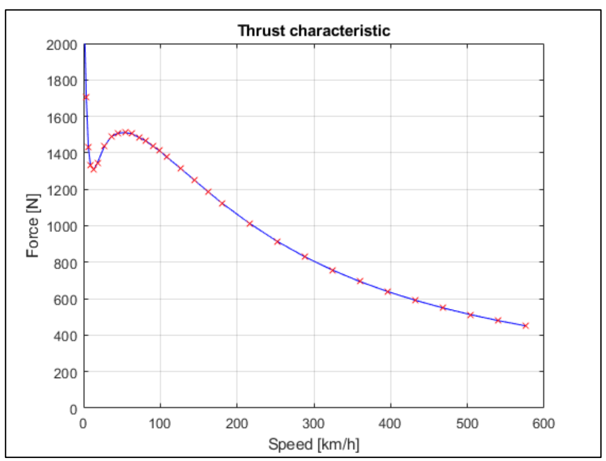
EPFLoop Research

- LIM limitation vs infrastructure cost
- What about lift ?
- Per coil approach





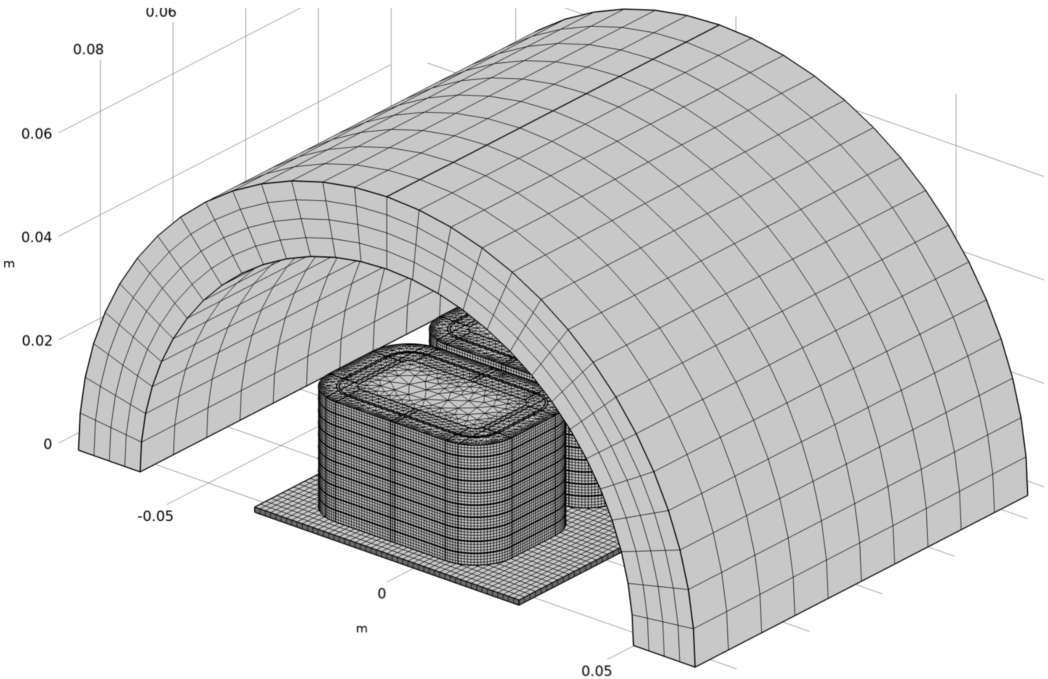


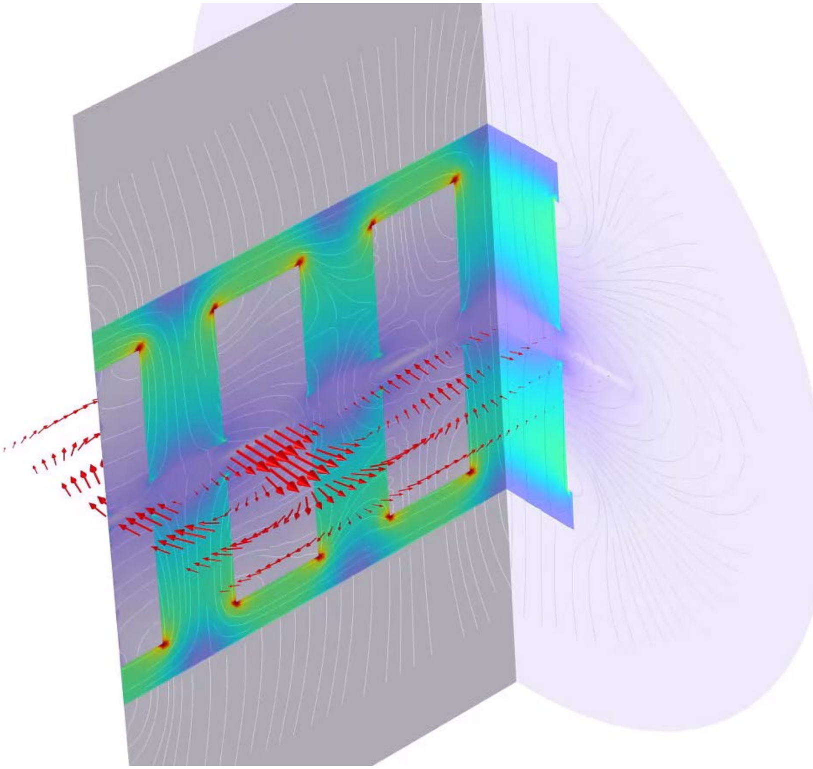



SEW

EPF | OOP

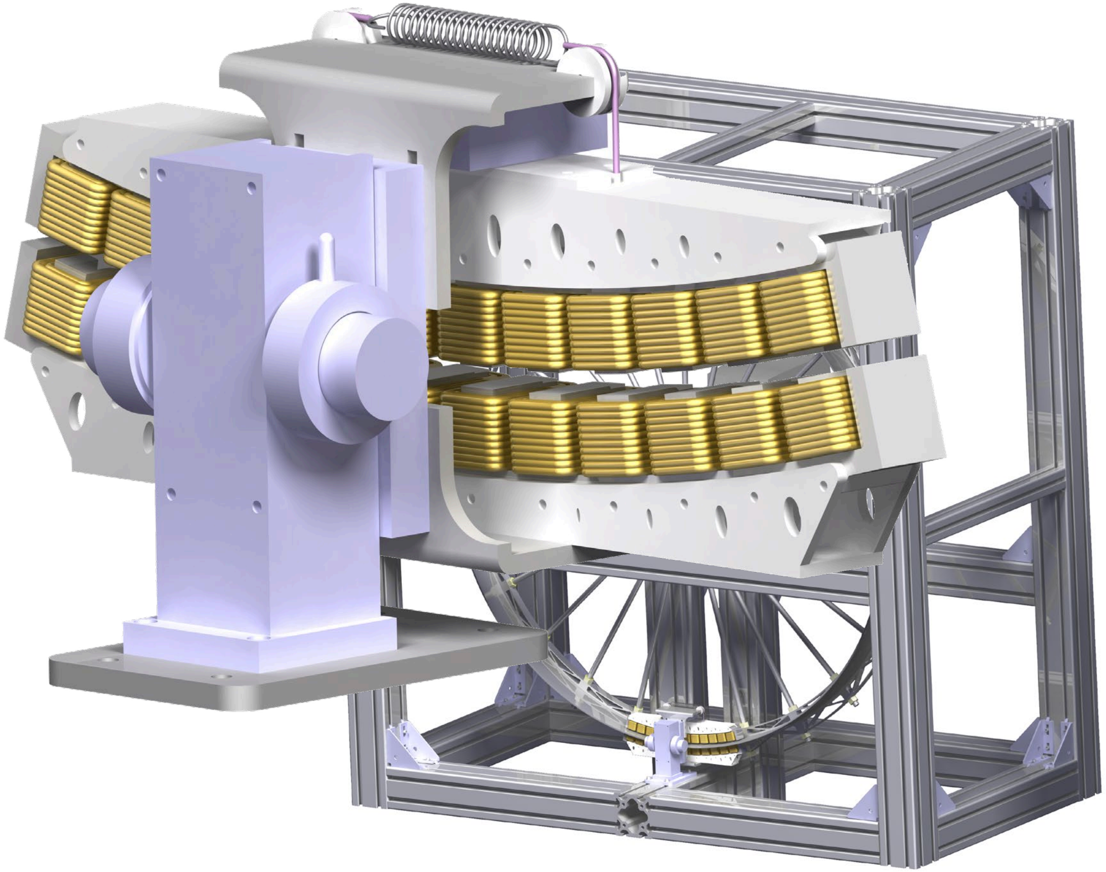
Design de moteurs linéaires à induction LIM





EPF | OOP

Développement d'un banc de test pour les moteurs à induction linéaire (LIM) et design de moteur



EPF | OOP

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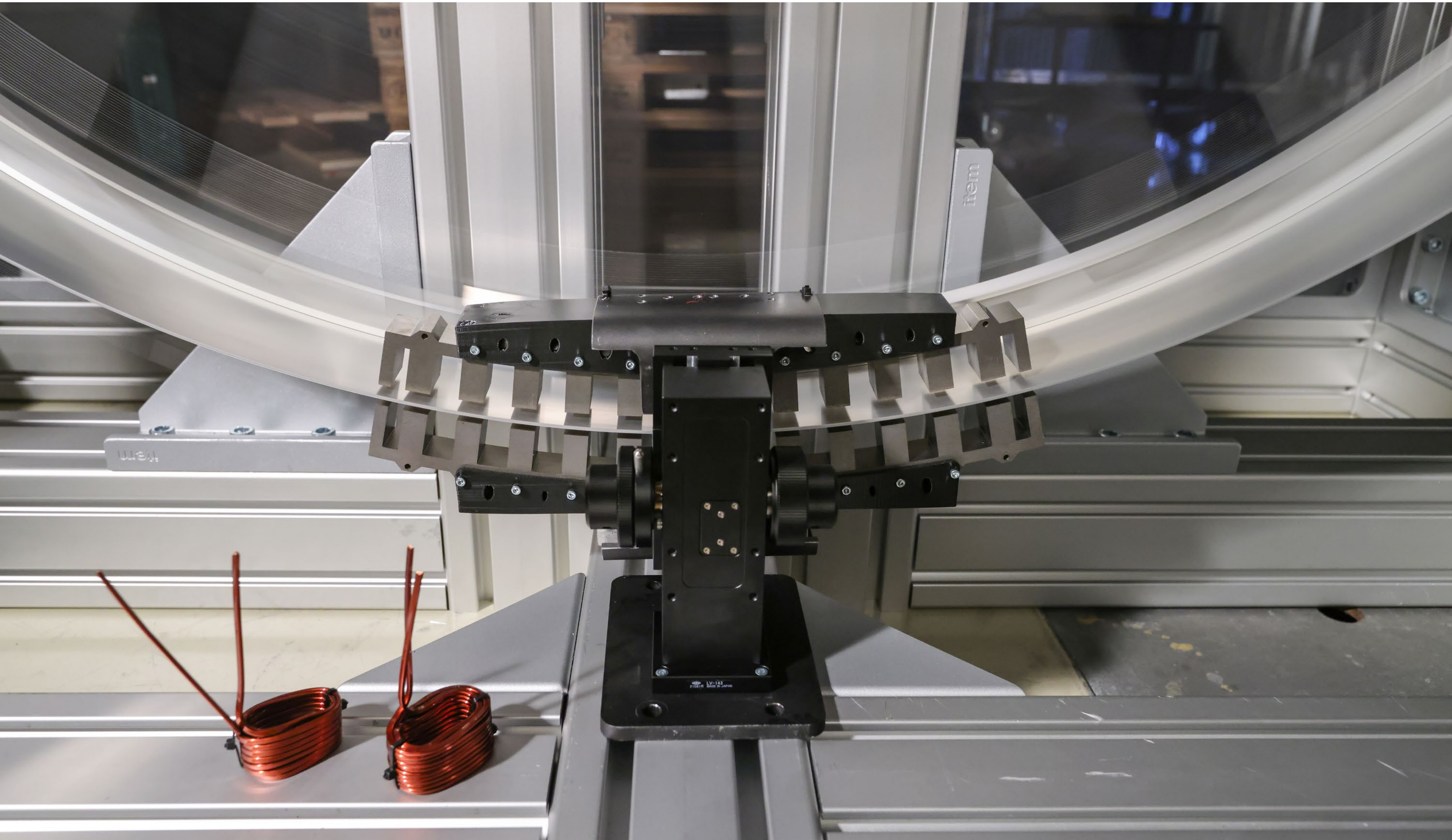
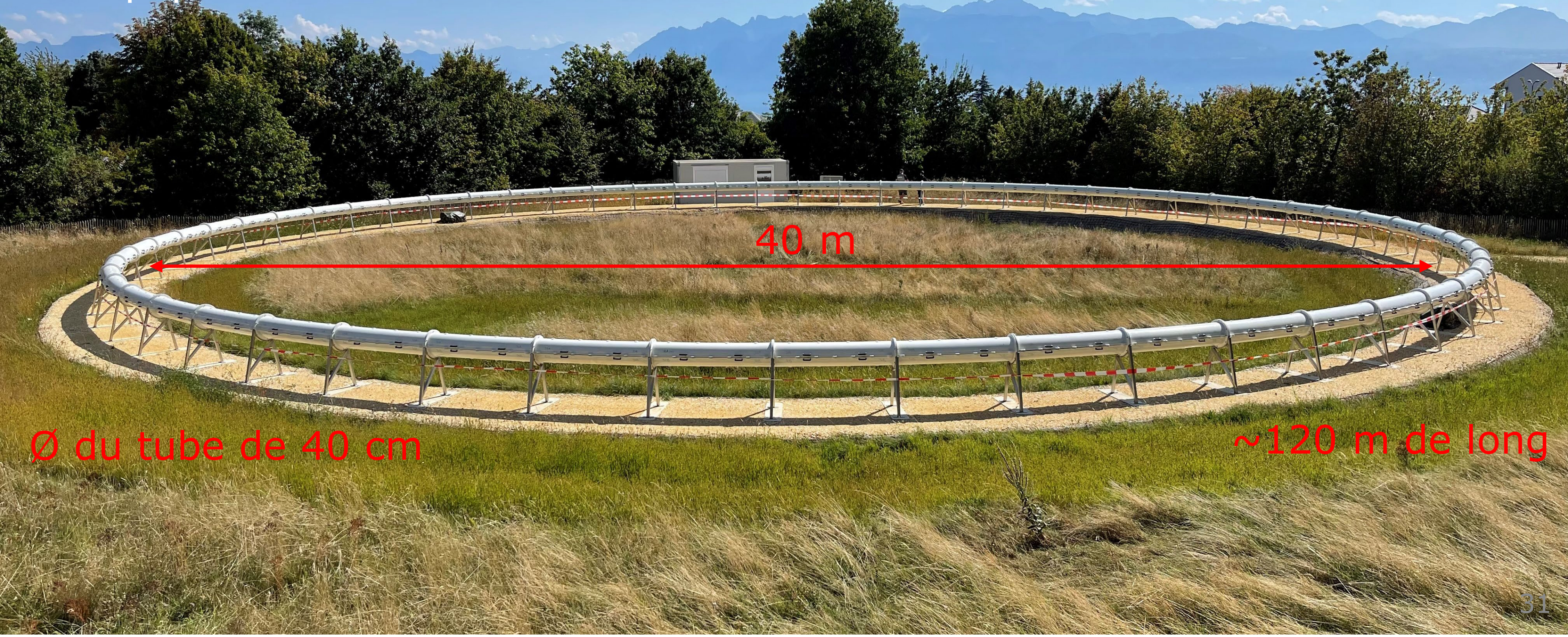


— E P F | O O P —

EPFL

La recherche continue

- 2 doctorants (1 financement innosuisse)
- Projets d'étudiants (semestre et PDM)
- Développement et mise en service d'une infrastructure
- Equipe de 5-7 étudiantes et étudiants + seniors et advisors




Infrastructure Pressure
863 mbar


Swiss Solar Boat
makita
CGN
aventron
zesst
EPFL
maxon
BATEMO
csem
Swiss
Solar
Boat

Swiss Solar Boat

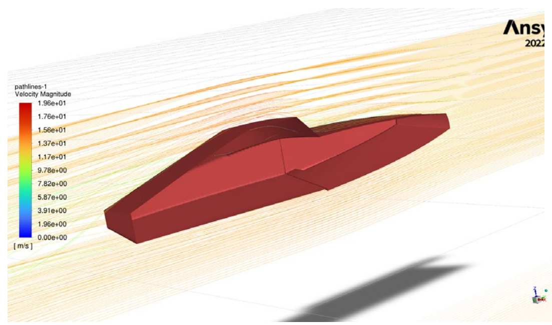
Swiss Solar Boat

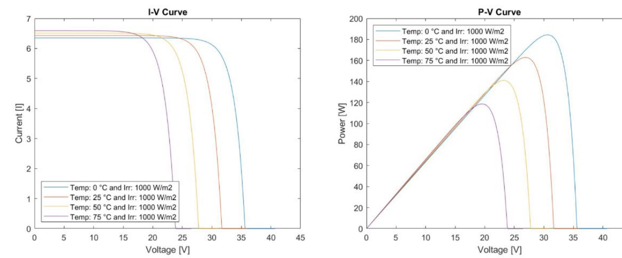
Swiss Solar Boat

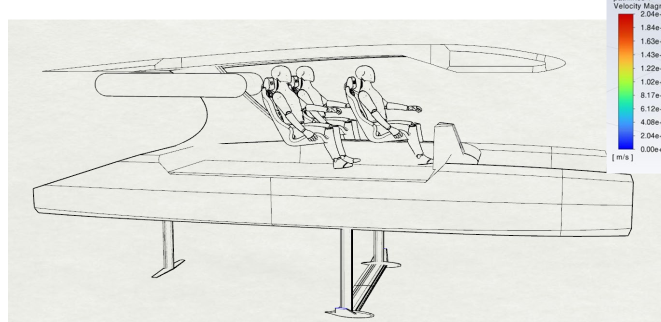
New horizons 2025-2026

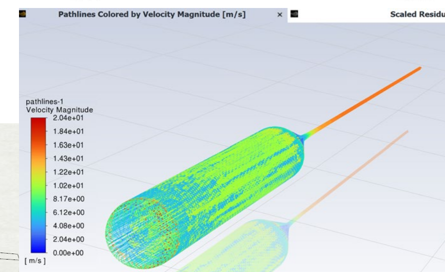
Definition of the project:

- **Flying boat**
- **Powered by hydrogen and solar energy**
- **3 passengers**
- **Autonomy: 150 km**
- **Cruising speed : 25kts**
- **Top speed : 35kts**







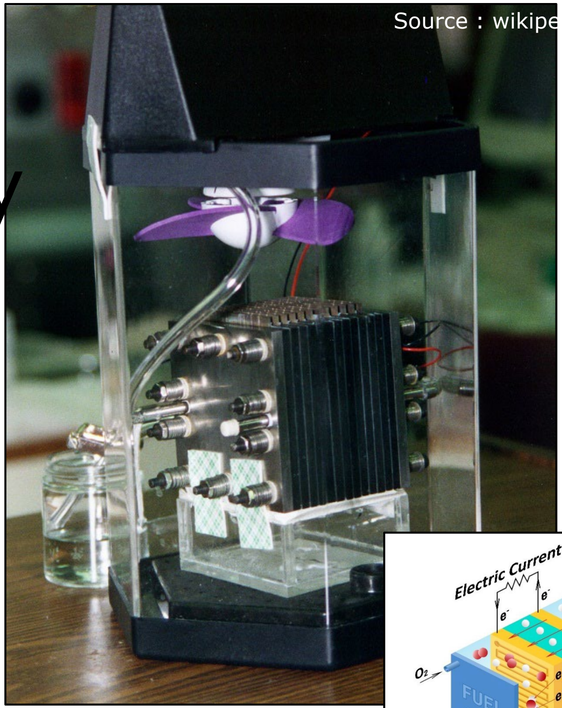


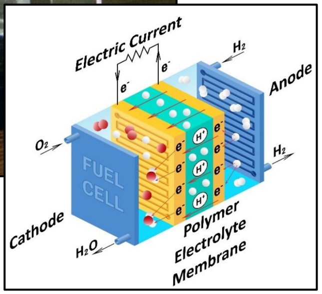
Densifying on-board energy

~200 W/m2

Li battery:
0.2 kWh/kg

Hydrogen :
33.33 kWh/kg





Solar energy coupled with storage in lithium batteries shows its limits in terms of on-board density. This is why Swiss Solar Boat is focusing on a denser energy vector:

green hydrogen

to increase the boat autonomy.

EPFL Racing Team

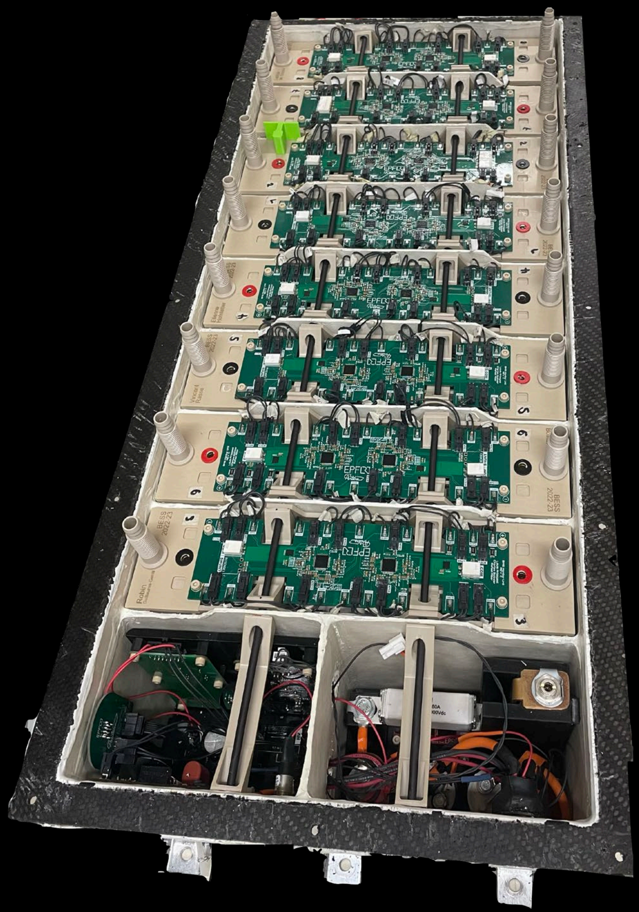
EPFL Racing Team

- **Codename : Sirius**
- **Masse : 243 kg (avec Driverless)**
- **Driverless**
- **Torque vectoring**

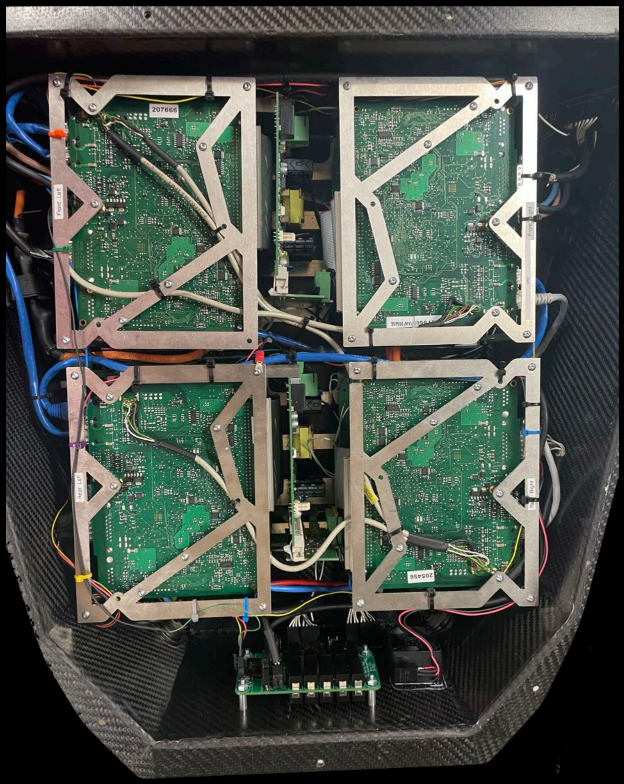
- **4 moteurs de 35 kW**
  - **Puissance max 140 kW (190 CV) limité à 80kW**
  - **> 100 kW de freinage régénératif**
- **Batterie**
  - **Custom BMS**
  - **Casing en composite**
  - **Capacité de 9.3 kWh**

EPFL

Batterie



Contrôleurs moteurs



Driverless

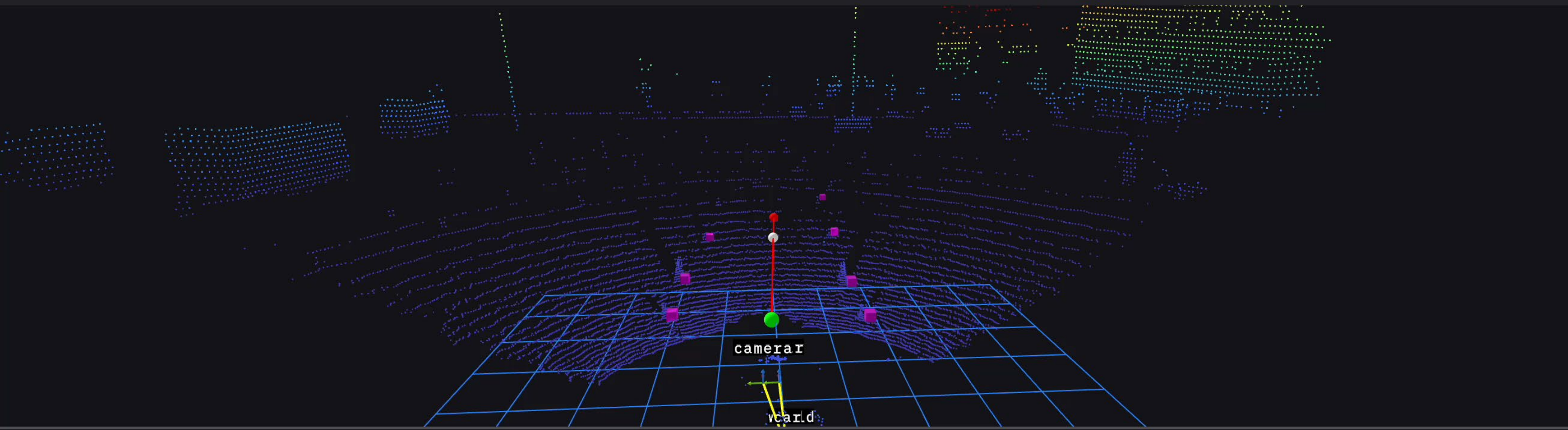
EPFL Racing Team

FS France 2024

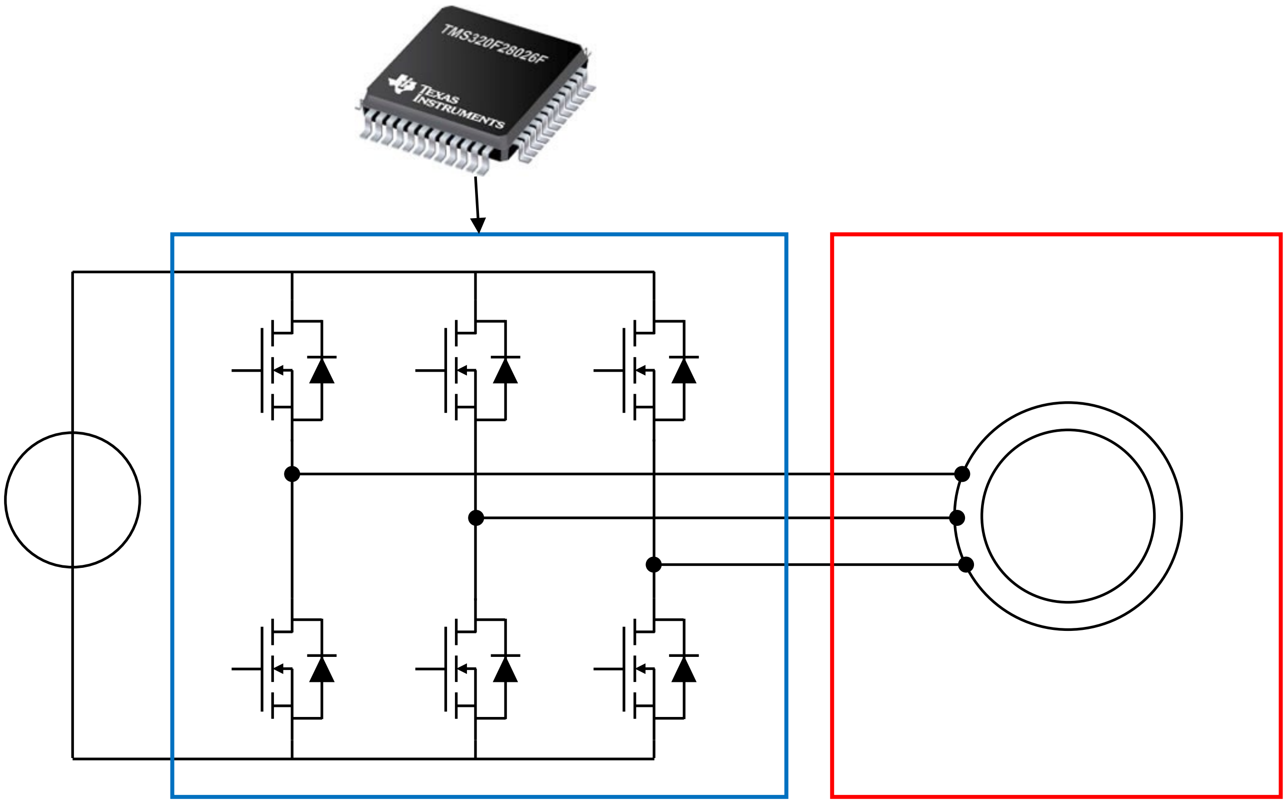
- 2ème au Design
- 2ème au Business Plan
- 3ème au Cost and manufacturing
- 1er à l'Acceleration Event
- 1er à l'Efficiency Event
- 3ème Overall

EPFL


EPFL
127
EPFL
Garrett
Swissquote
E·M·C
EPFL
127
Altium
Garrett
EPFL
127
BATEMO
Swissquote
E·M·C
LEMO


camerar

Entraînement électrique - Drive



Electronique de puissance Machine électrique

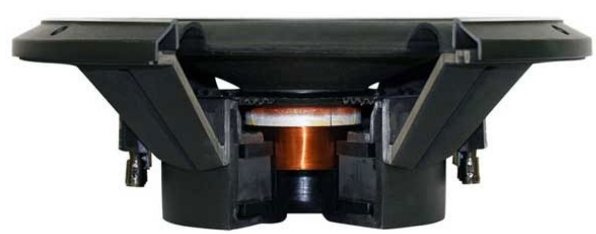
Convertisseurs électromécaniques

Actionneurs

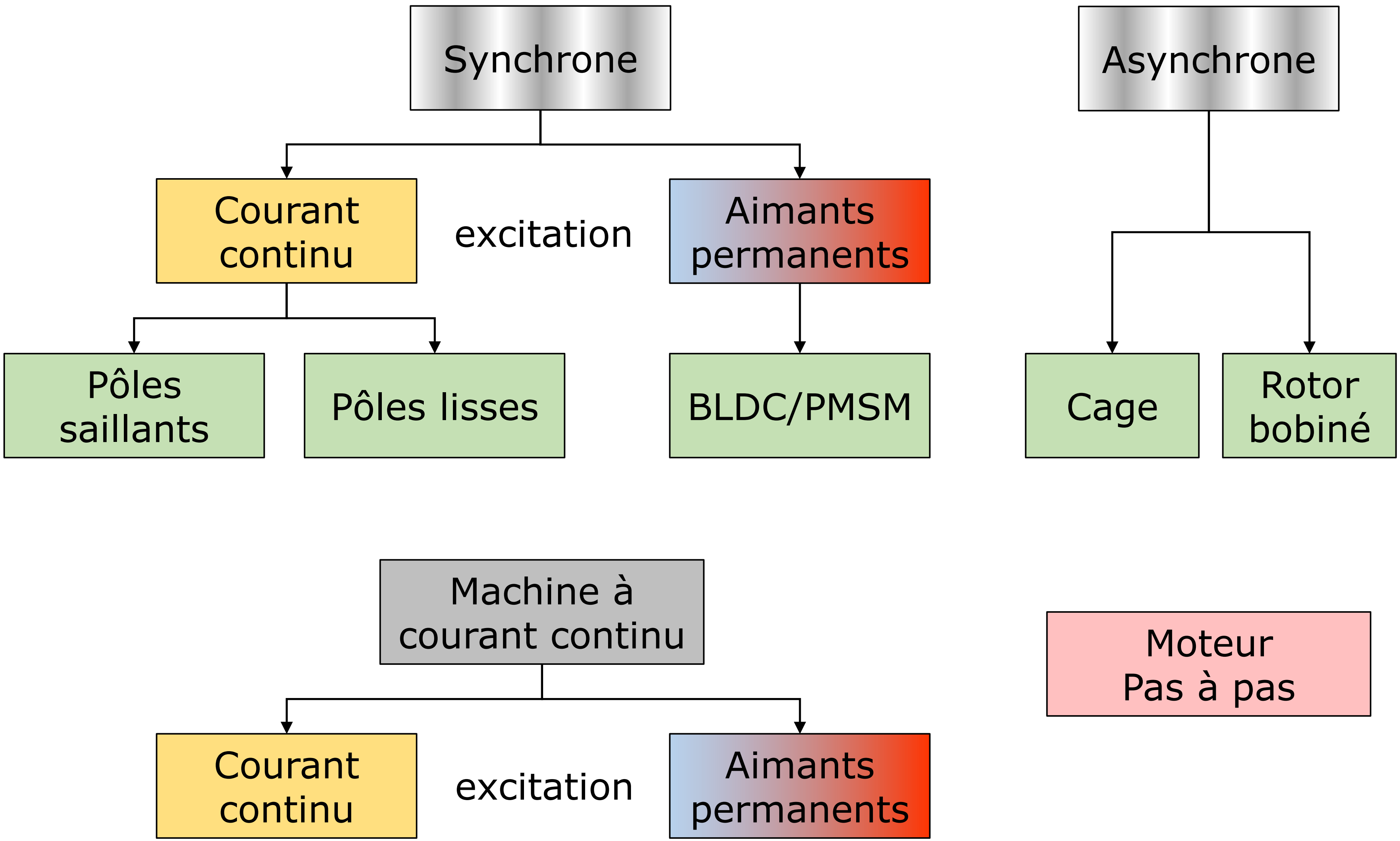
Machines électriques

- **Système réluctant** — Relais, serrures
- **Système électrodynamique** — Voice coil
- **Système électromagnétique** — (-)
- **Système réluctant polarisé** — Certains actionneurs linéraires bistables utilisés dans l'automation

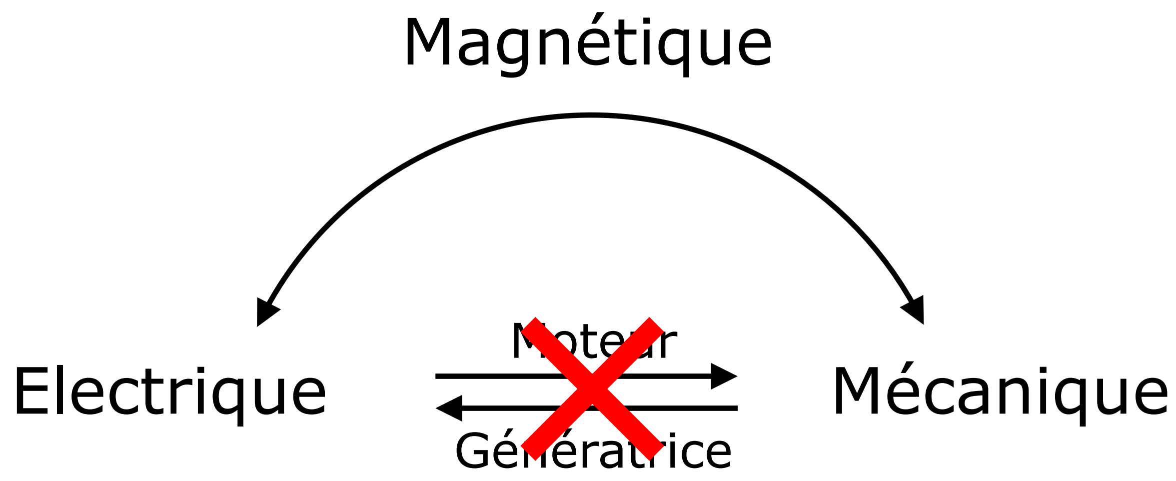


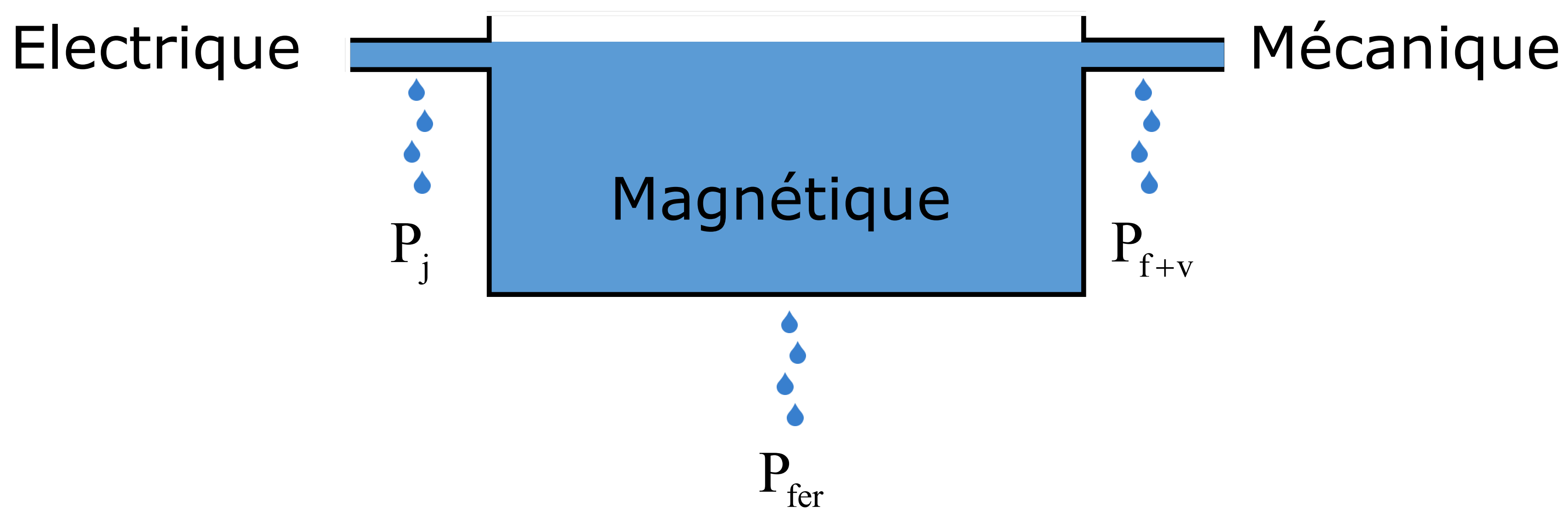



Machines électriques



Conversion d'énergie électromécanique



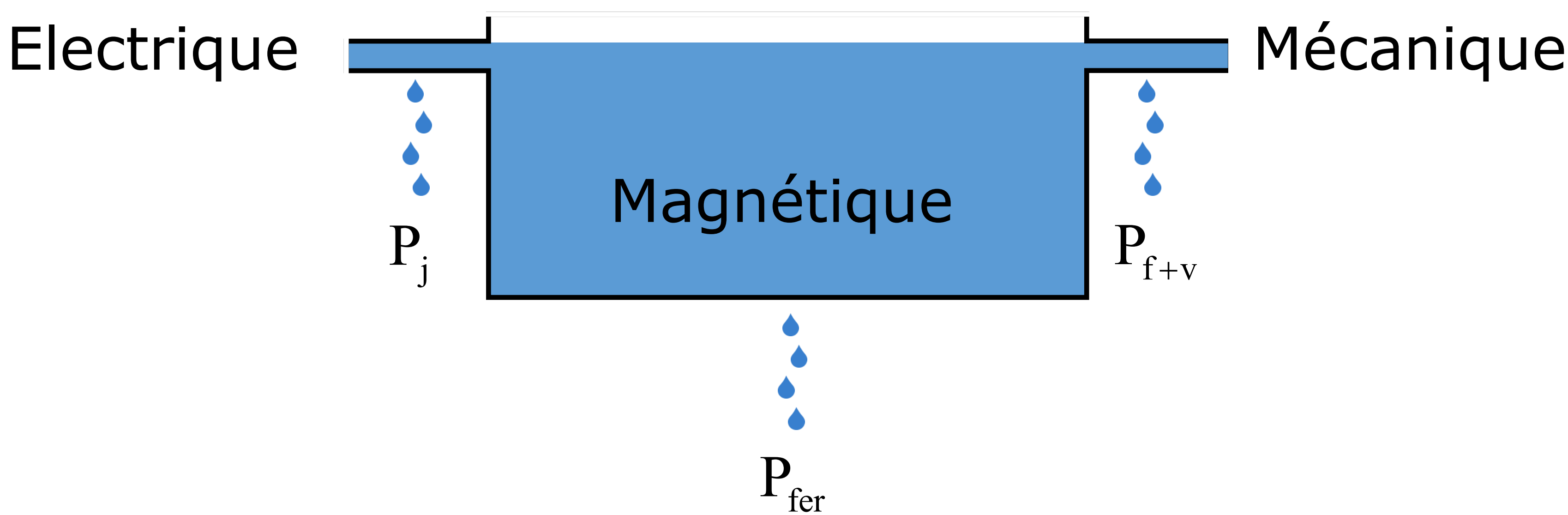


Couple électromagnétique

Conversion d'énergie électromécanique (4 formes d'énergie) :

- énergie électrique
- énergie mécanique
- énergie thermique (pertes)
- énergie magnétique (emmagasinée dans le champ de couplage)

$$W_{mag} = \frac{1}{2} L i^2 \qquad -\frac{\partial W_{mag}}{\partial \theta_m} = T_{em}$$



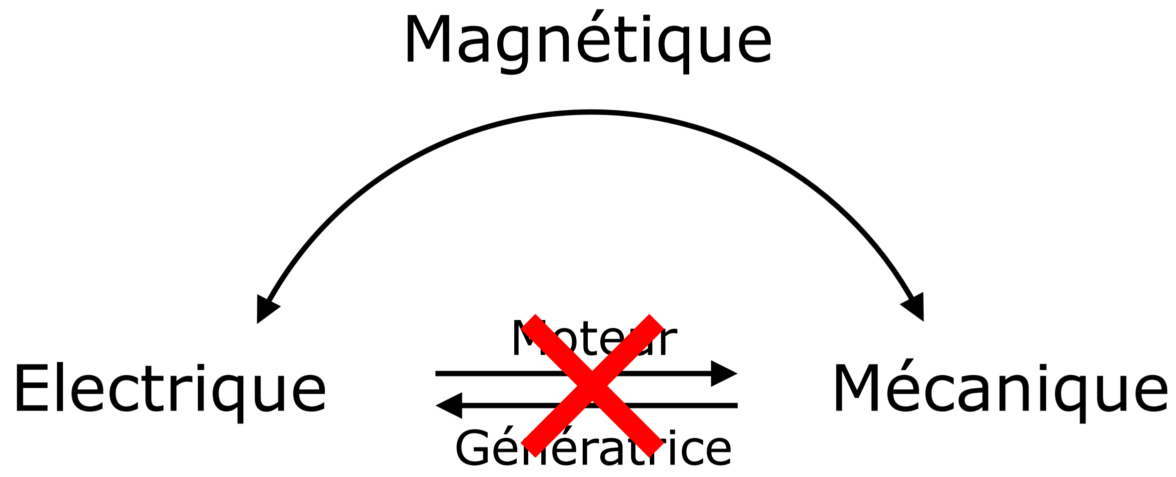
Couple électromagnétique

Loi de Newton :

$$\vec{F} = m\vec{a}$$

$$\boxed{\Sigma T = J\frac{d\Omega}{dt}}$$

$$\frac{T_{em} - T_{frottements}}{J} = \frac{d\Omega}{dt}$$



Couple électromagnétique

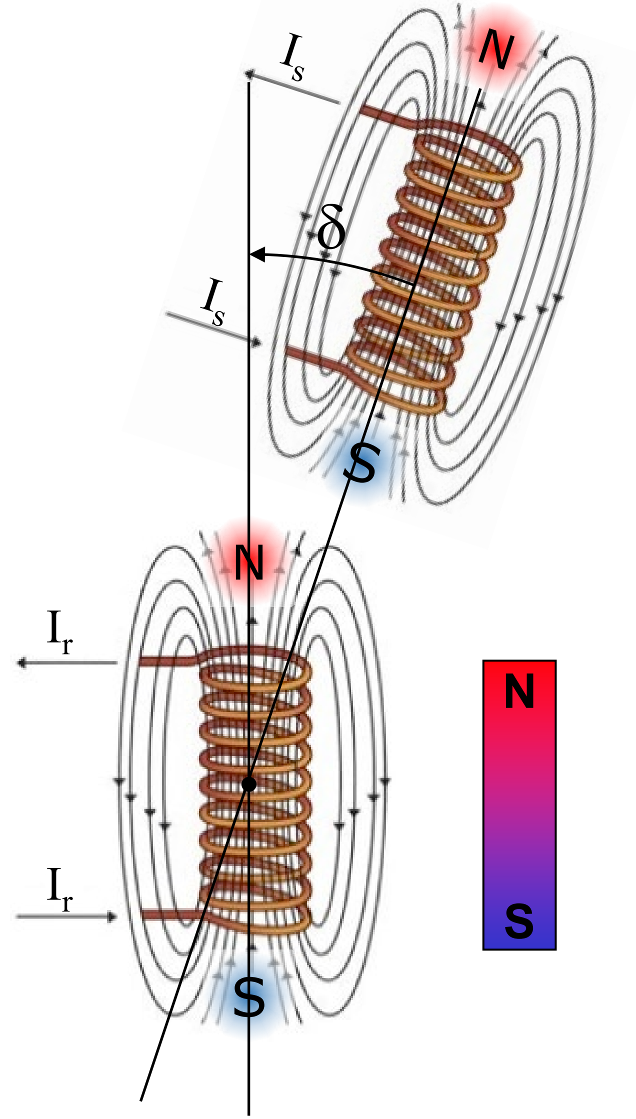
Génération d'un couple par interaction de champs magnétiques

$$T_{em} = k \hat{B}_s \hat{B}_r \, p \sin\delta$$

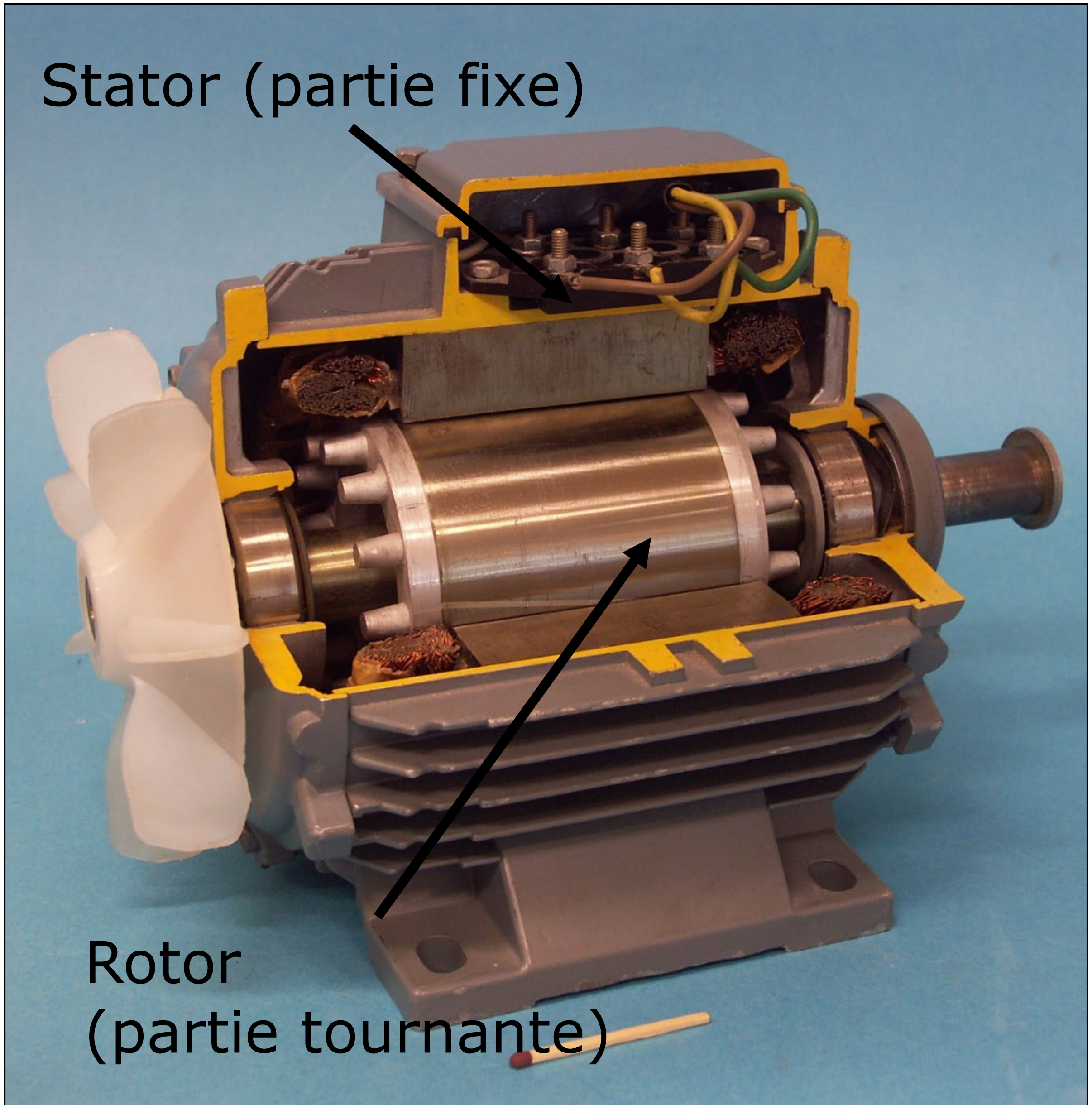
Nombre de paires de pôles

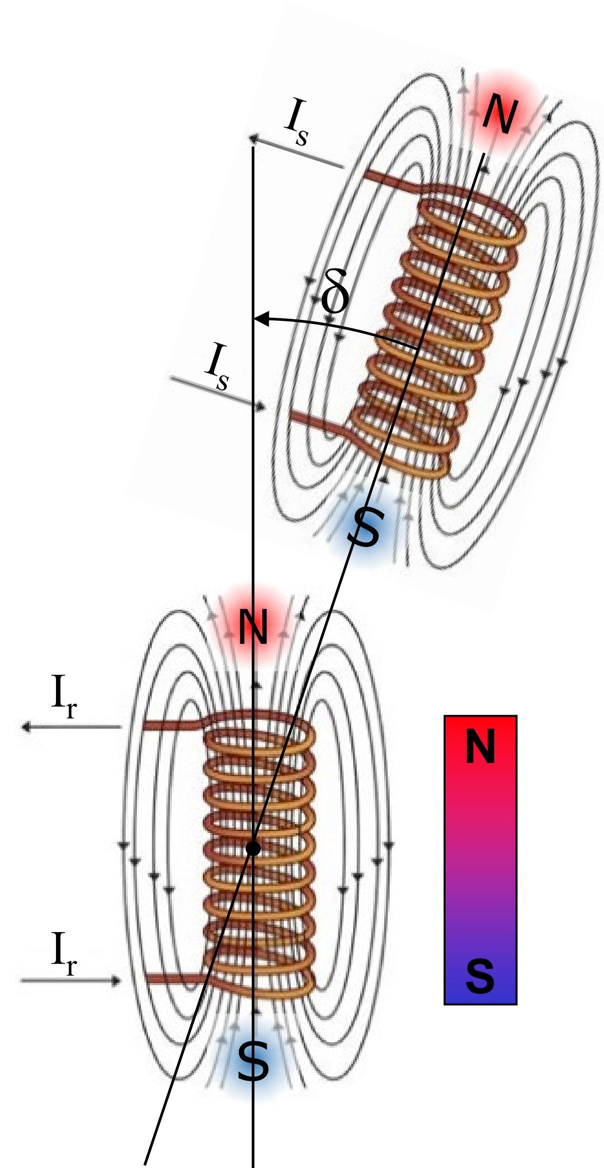
Différents types de machines :

- Machine asynchrone
- Machine à courant continu
- Machine synchrone
- Moteur synchrone à aimants permanents
- Moteur pas à pas



Constitution d'une machine électrique



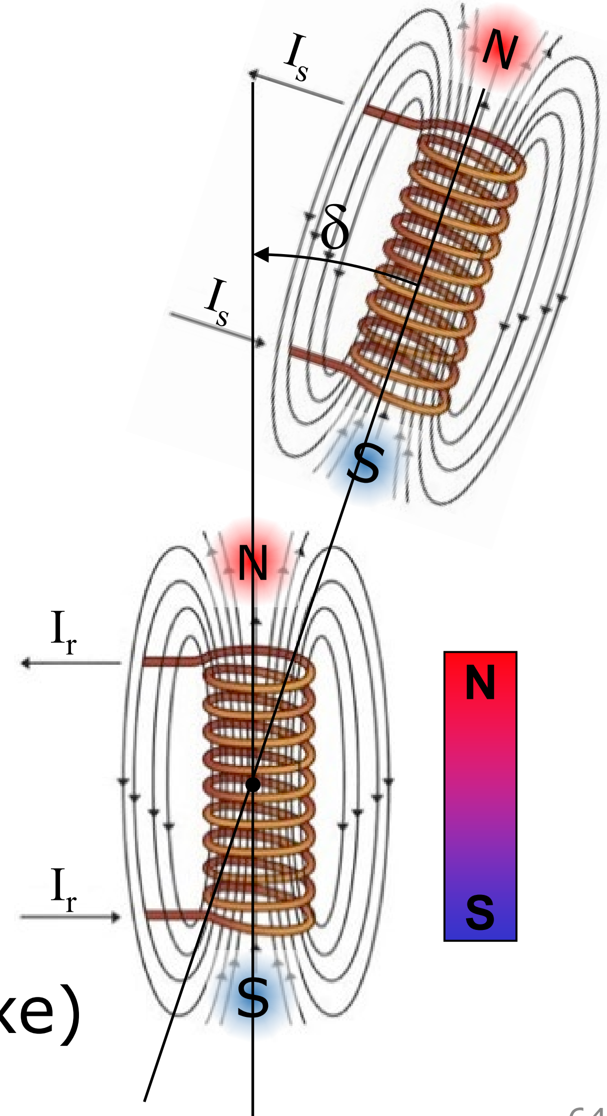


Constitution d'une machine électrique

Outrunner

Rotor
(partie tournante)

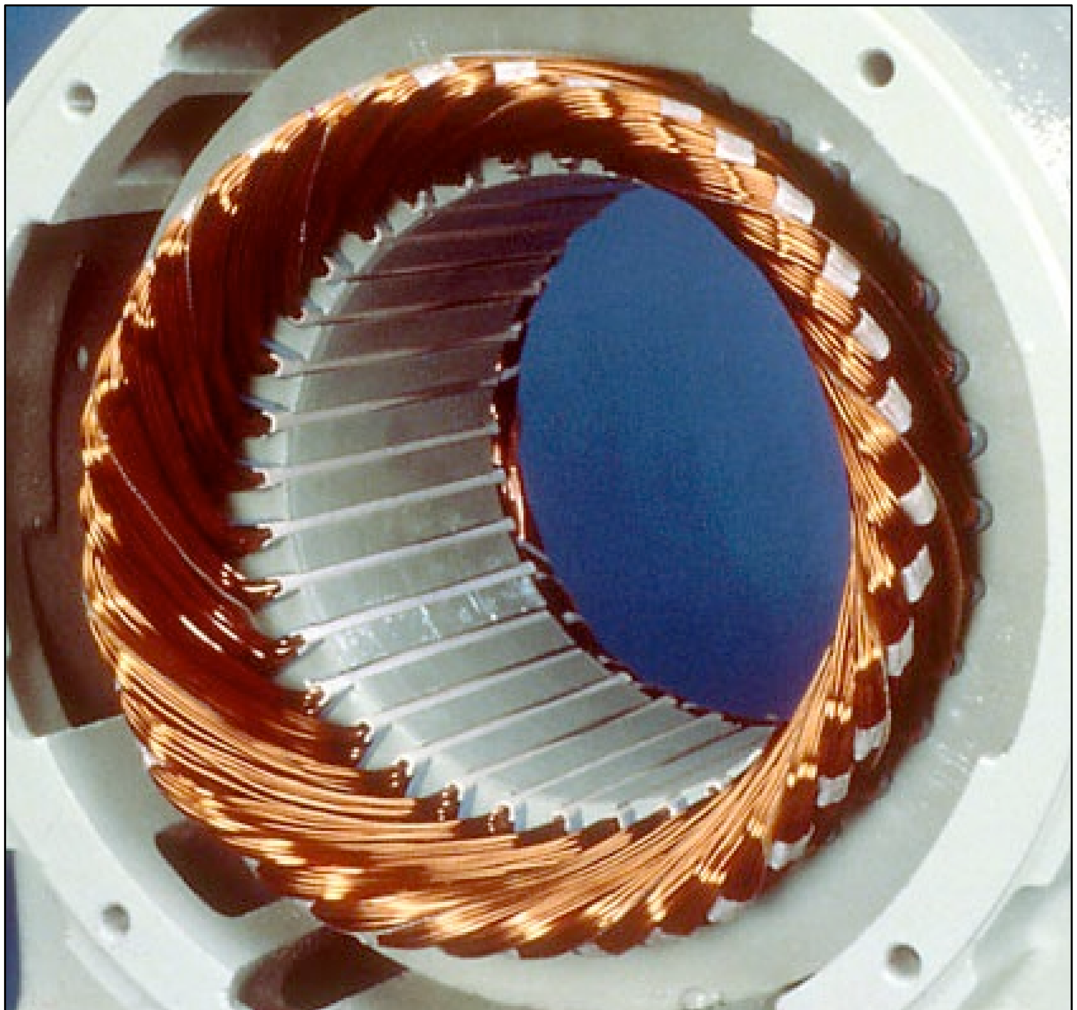
Stator (partie fixe)

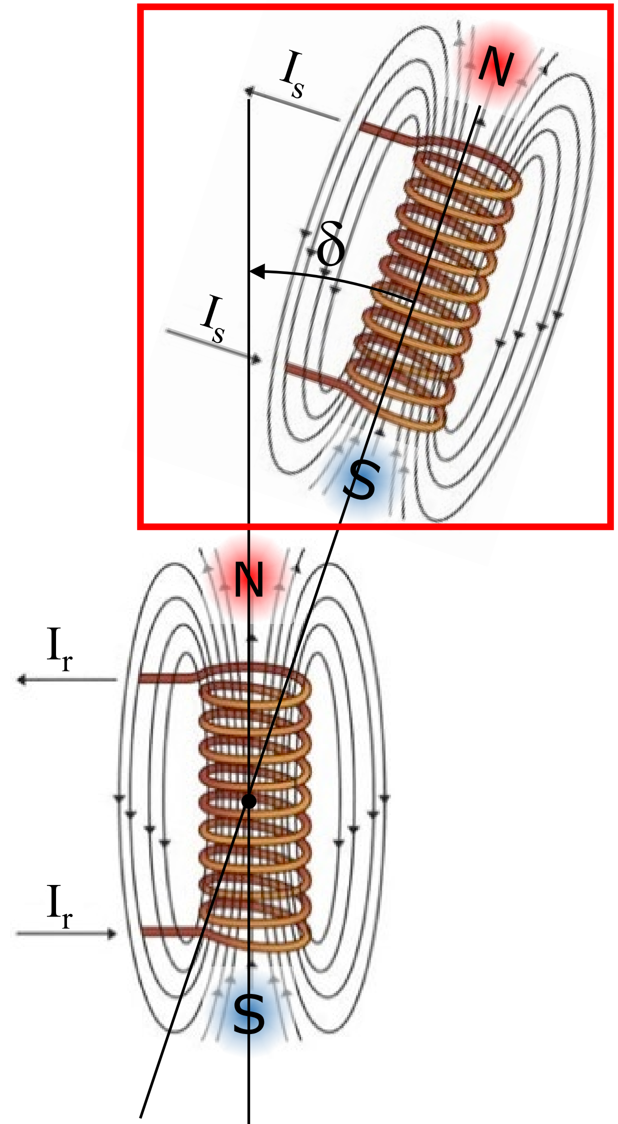


Source :
robots-et-compagnie.com

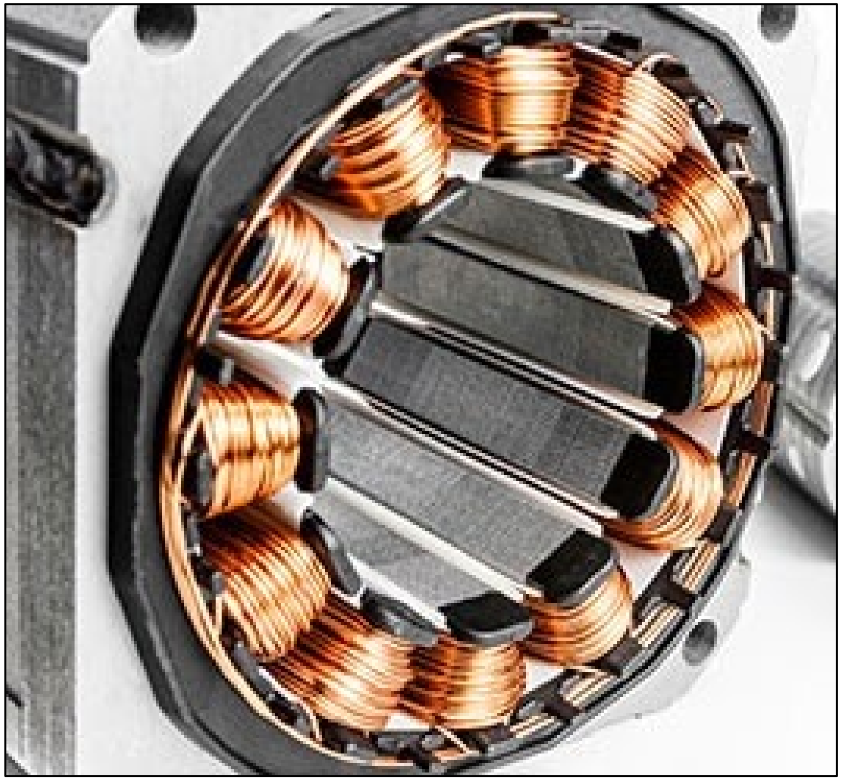
Champ d'induction magnétique crée au stator

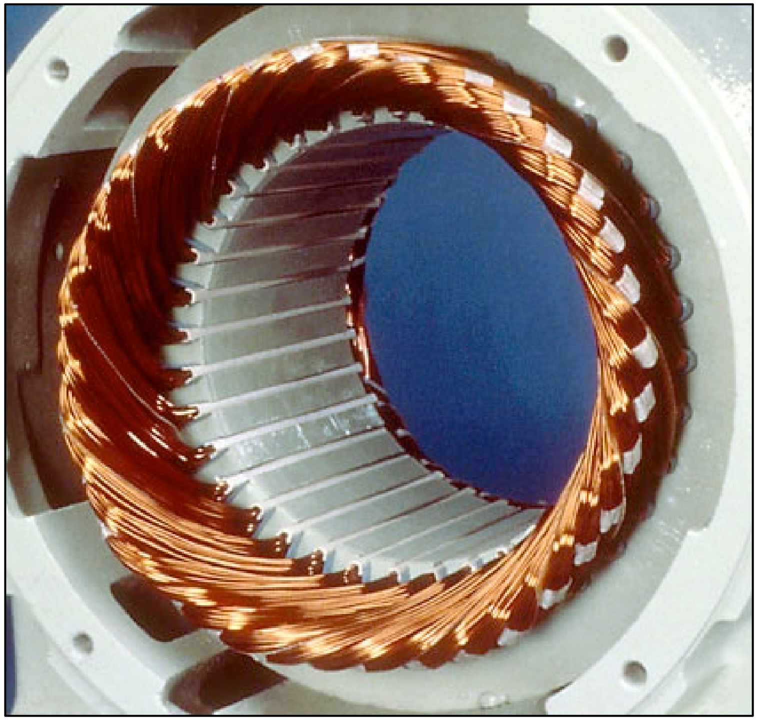
Le champ d'induction magnétique au stator est crée par un courant électrique présent dans un enroulement (bobines).

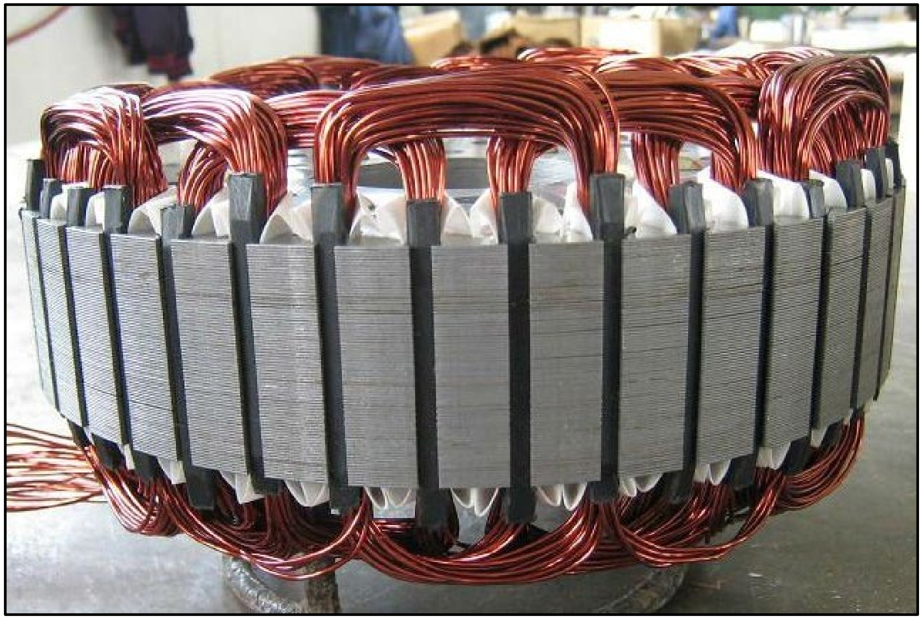




Stator







Couple électromagnétique

Génération d'un couple par interaction de champs magnétiques

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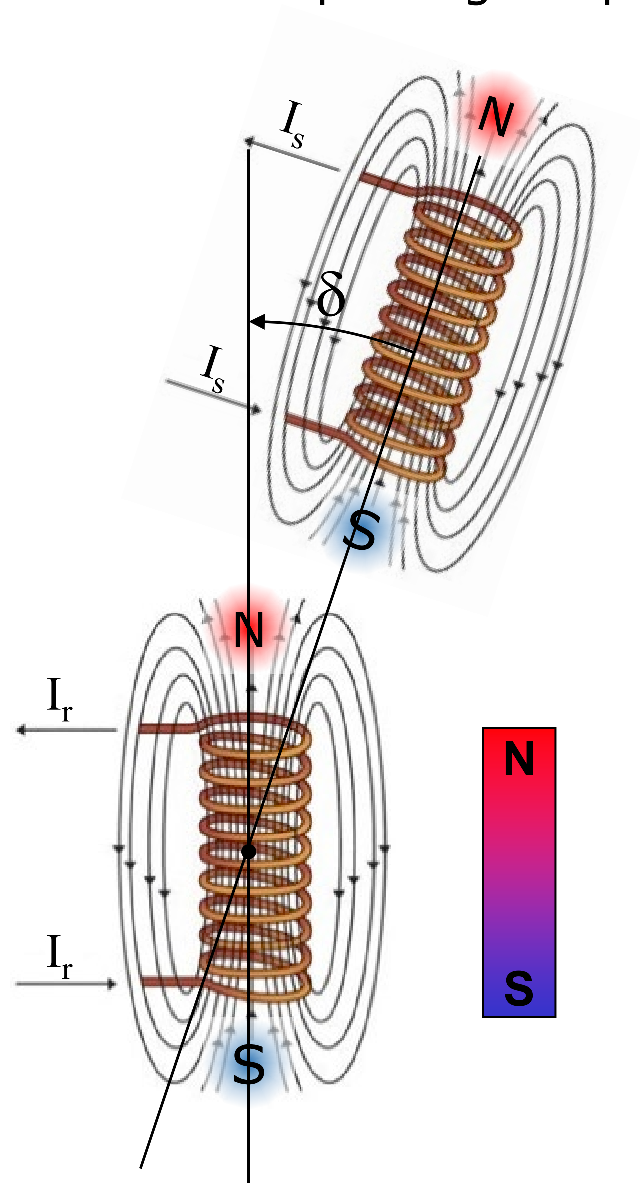
Nombre de paires de pôles



Différents types de machines :

- Machine asynchrone
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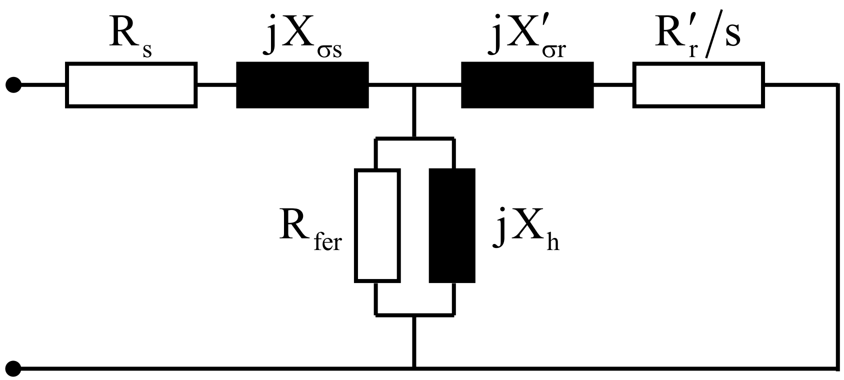
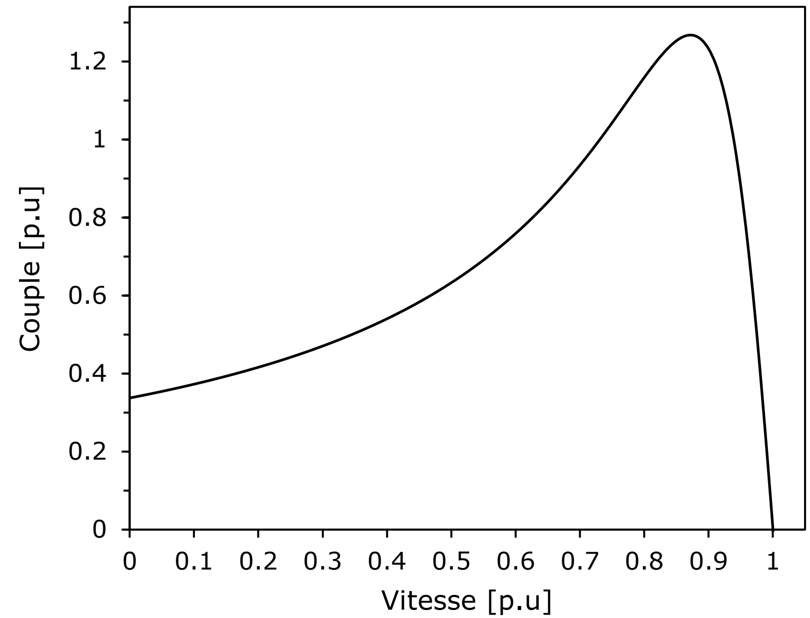
- Moteur synchrone à aimants permanents
- Moteur pas à pas

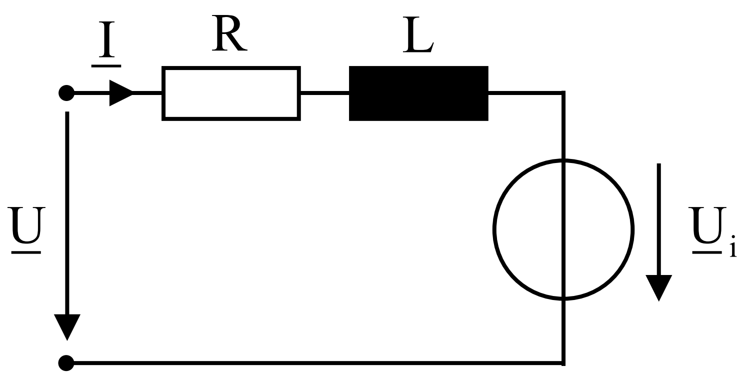
Caractéristique de couple et schémas équivalents

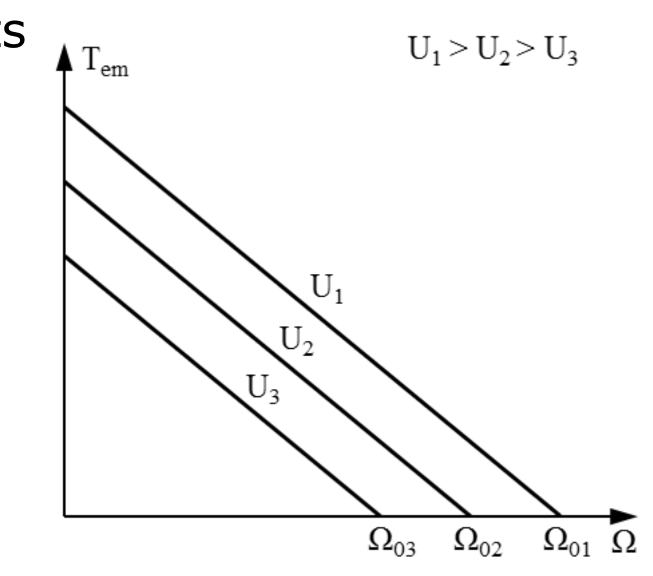
Machine asynchrone





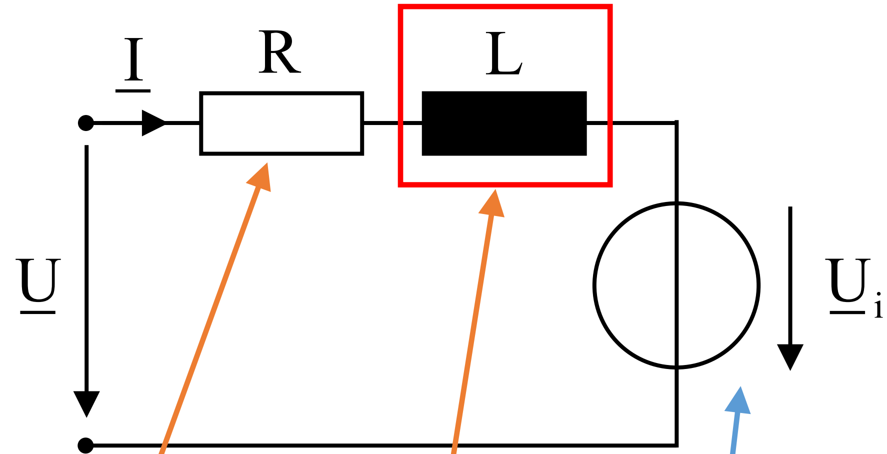
Moteur synchrone à aimants permanents

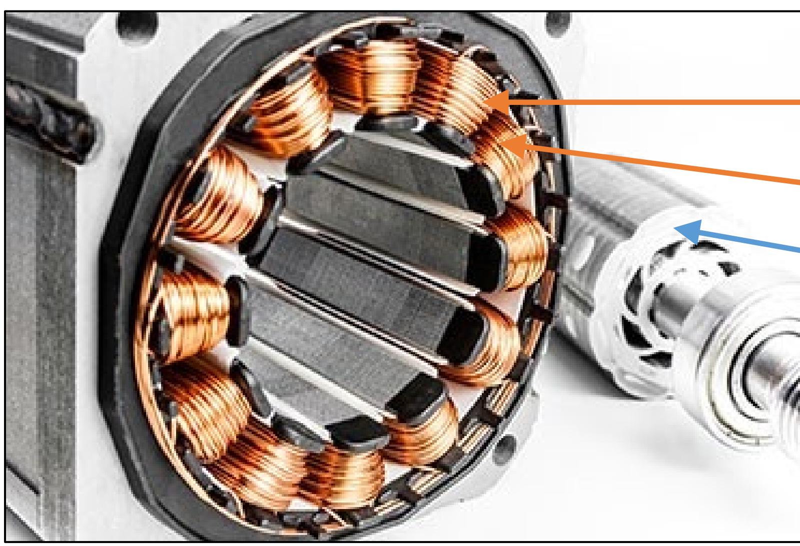




Inductances

Schéma équivalent d'un moteur synchrone à aimants permanents





Résistance (du fil de la bobine)

Inductance (de la bobine)

Effet de la rotation du rotor

Source :
robots-et-compagnie.com
rs-online.com

Inductances

Schéma équivalent d'une machine à courant continu

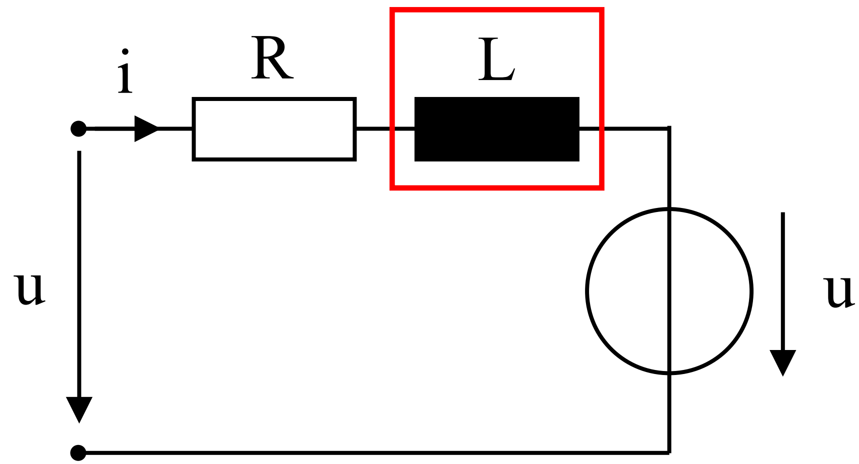
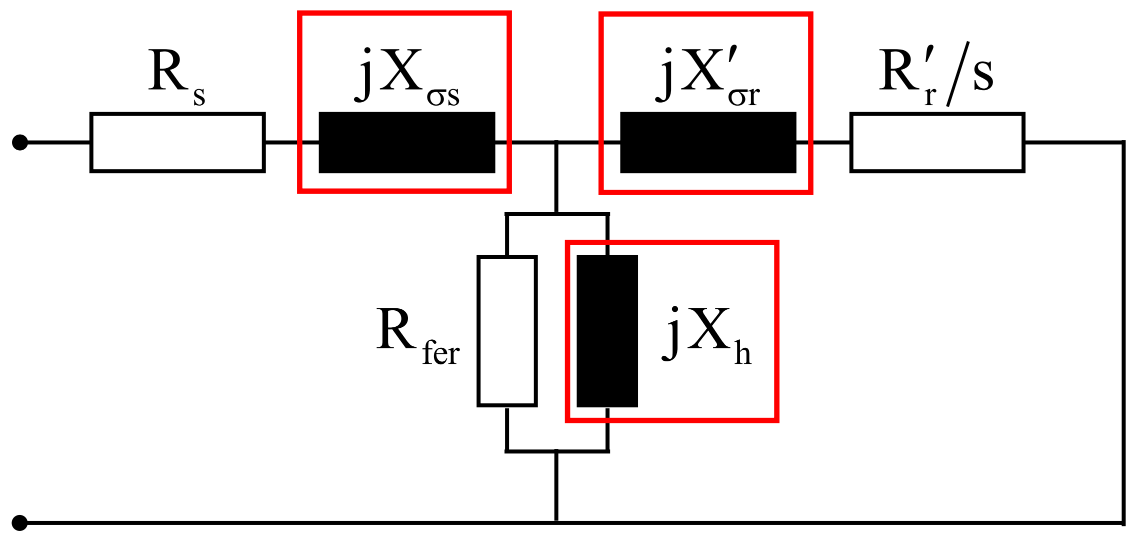


Schéma équivalent d'une machine asynchrone



$$X = \omega L \quad [\Omega]$$

Inductances

Différentes inductances :

- Inductance propre
  - Inductance de fuite
  - Inductance de champ principal

$$L = \frac{\Psi}{i} = N^2 \Lambda \quad [H]$$

- Inductance mutuelle

$$L_{21} = \frac{\Psi_2}{i_1} = N_1 \, N_2 \, \Lambda_{21}$$

Perméance : $\Lambda = \mu \frac{S}{l}$

μ : perméabilité
S : section
l : longeur moyenne

Flux totalisé : Ψ