Smart Electricity Grids Metrology

DC/DC Converters for MVDC grids

Bruno LEFEBVRE

16/05/2024

SuperGrid Institute

Shaping power transmission

SuperGrid Institute: your partner for innovation

Developing key technologies for future electricity grids

Visit our website
www.supergrid-institute.com

SuperGrid Institute:

- European leader in HVDC & MVDC technologies & services
- Private research & innovation company
- Pooling the expertise of industrialists and academics
- Equipped with state-of-the-art test platforms
- Member of:

cigre · fit FRENCH INSTITUTES OF TECHNOLOGY · GIMELEC · IEEE · IEC International Electrotechnical Commission

100+ patent applications

60+ PhD students

360+ international publications

26 nationalities

78 M€ of investment

155 collaborators

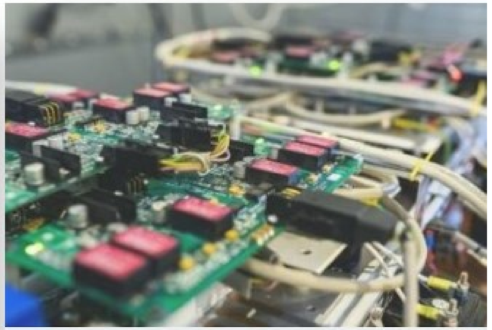
SuperGrid Institute
Shaping power transmission

Our areas of expertise

Covering the full technological chain of future power grids

Supergrid Architecture & Systems

High Voltage Substation Equipment



Power Electronics & Converters

High Voltage Cable Systems

Power Storage & Balancing

Agenda

1- Medium voltage direct current (MVDC)

- Architecture & Concept
- Evolution

2- DC-DC converters

- Architecture & Components
- Topologies
- Case study

3- Conclusion

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MVDC systems

High Voltage Direct Current (HVDC)

- Economically viable solution for long-distance and submarine transmission of bulk power
- 1st commercial system in 1954 in Sweden

Medium voltage direct current (MVDC)

- Emerging technology in power distribution and collection systems
- Pilot projects in China and Europe for PV, wind and other applications

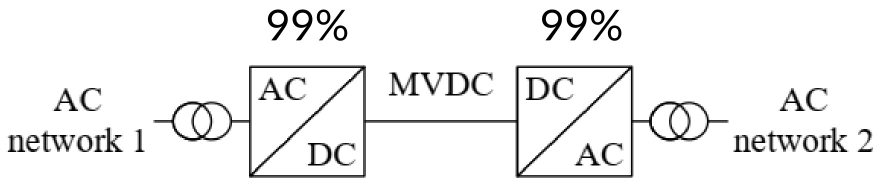
Scientific and technical community works on MVDC foundations

- CIGRE TB 793 “Medium voltage direct current (MVDC) grid feasibility study”
- CIGRE TB 875 “Medium Voltage DC distribution systems”
- CIRED TB “DC Networks on the distribution level – New trend or Vision?”
- IEEE Std 1709-2018 Recommended Practice for 1 kV to 35 kV Medium-Voltage DC Power Systems on Ships
- CIGRE WG A3.40 MVDC switchgear (ongoing)
- CIGRE WG B1.82 MVDC cable systems (ongoing)
- IET book “Medium Voltage DC System Architectures” edited by Brandon Grainger, Rik W. De Doncker

MVDC architecture

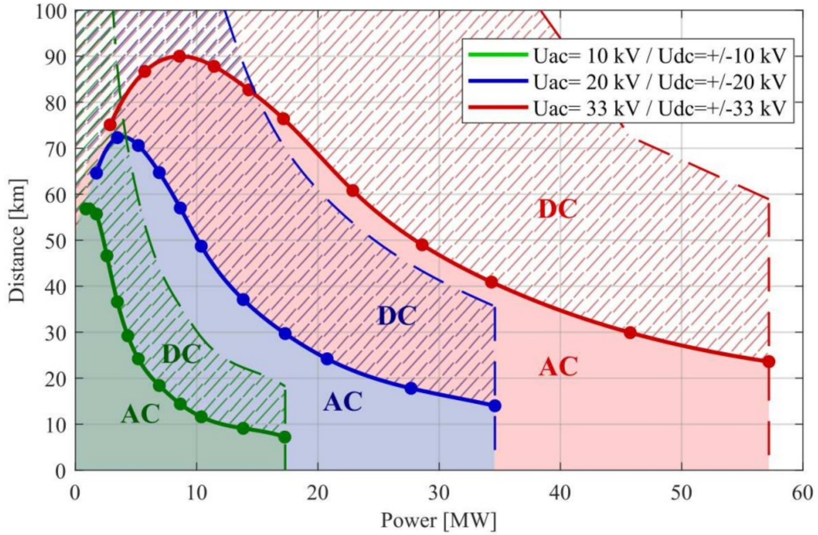
AC

DC



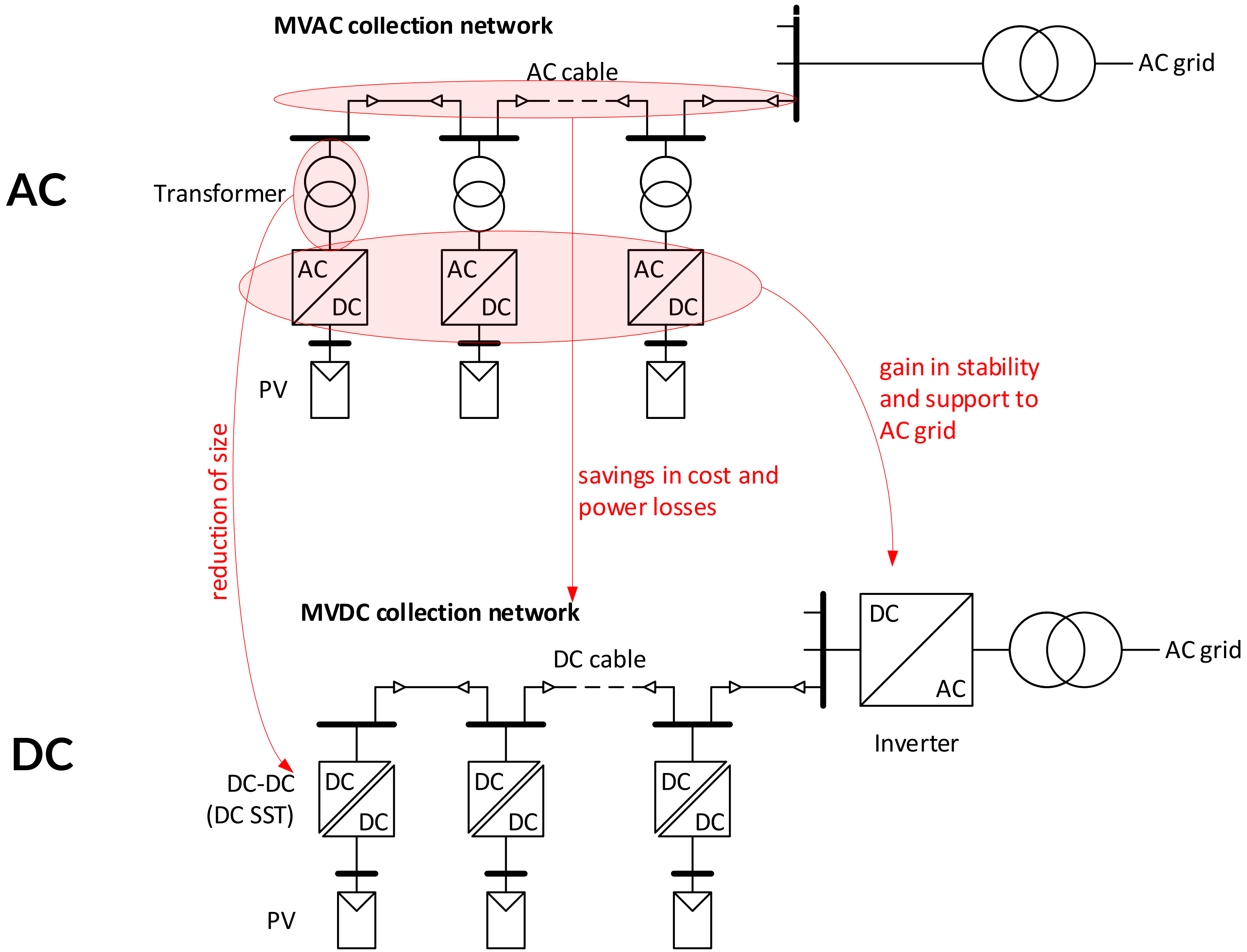
AC phase-phase RMS (U_{AC})	DC pole-ground ($U_{DC}/2$)
10 kV	±10 kV
20 kV	±20 kV
33 kV	±33 kV

	AC	DC
Technological maturity	⊕⊕⊕	⊖⊖⊖
Size of installations	⊖	⊕⊕
Efficiency	⊖	⊕
Controllability	⊖	⊕⊕



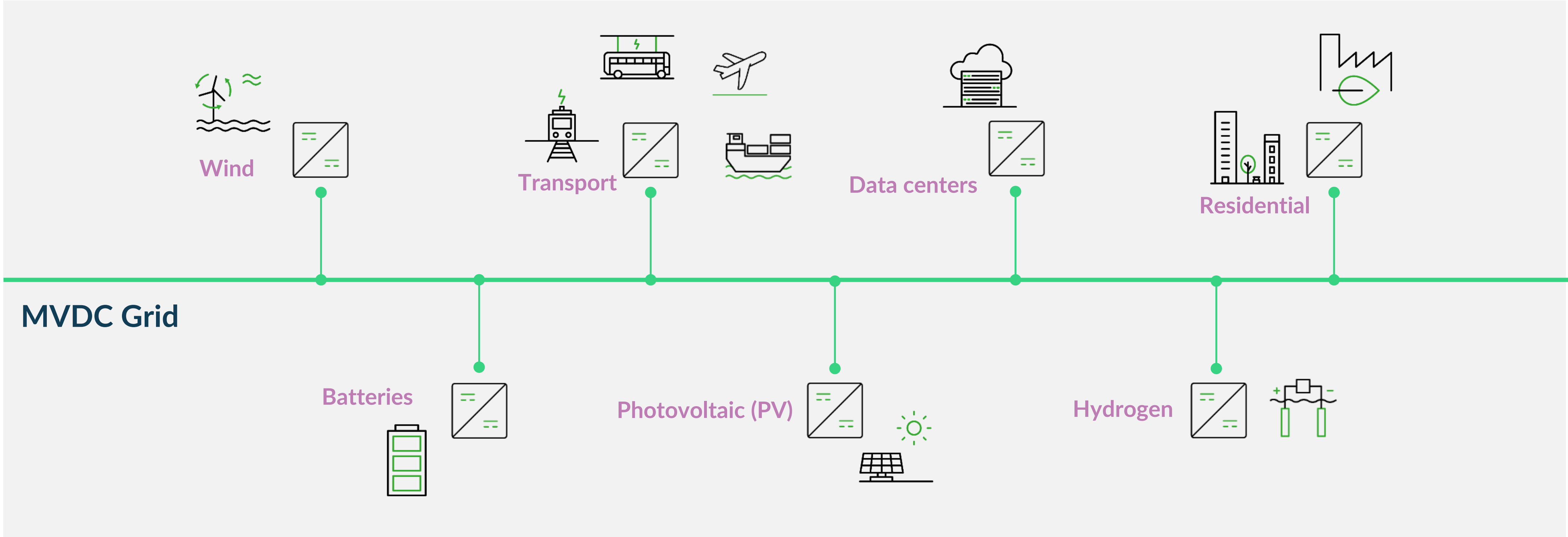
P. Le Metayer, J. Paez et al. “Break-even distance for MVDC electricity networks according to power loss criteria” EPE 2021

Advantages



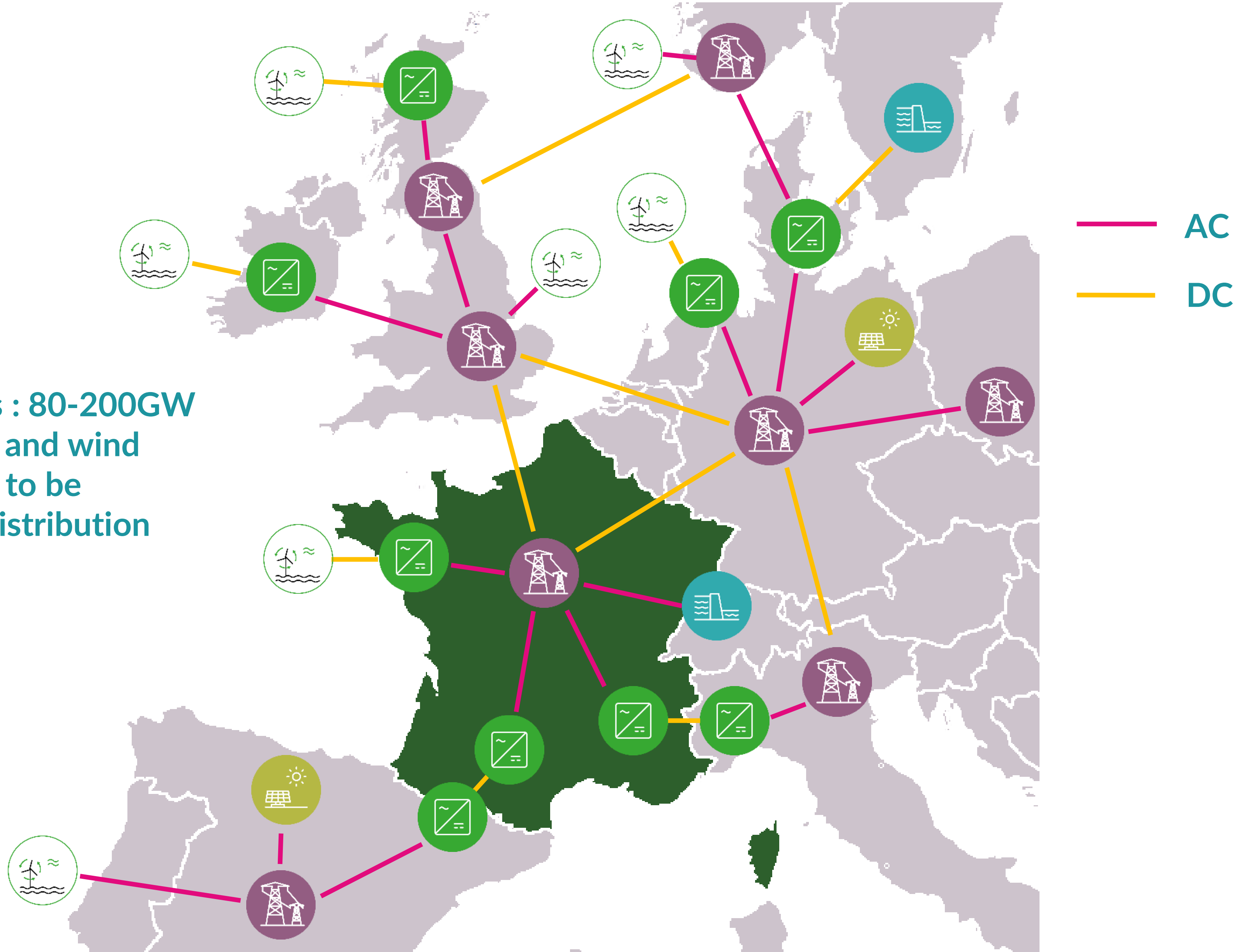
AC
MVAC collection network
AC cable
AC grid
Transformer
AC
DC
PV
reduction of size
gain in stability and support to AC grid
savings in cost and power losses
DC
MVDC collection network
DC cable
AC grid
Inverter
DC-DC (DC SST)
PV

Concept of MVDC Grid



European electrical network

Scenario Enedis : 80-200GW of photovoltaic and wind installed power to be connected on distribution level until 2050



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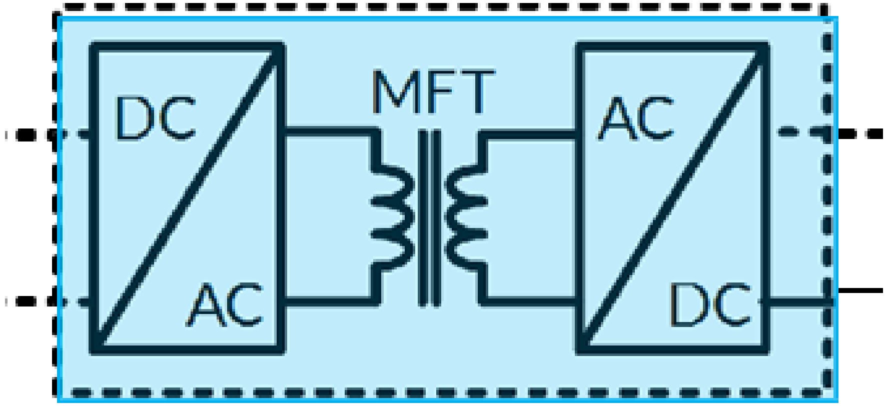
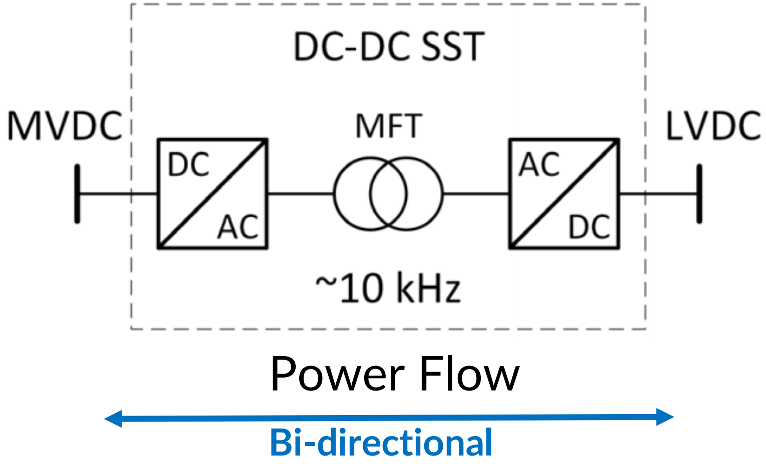
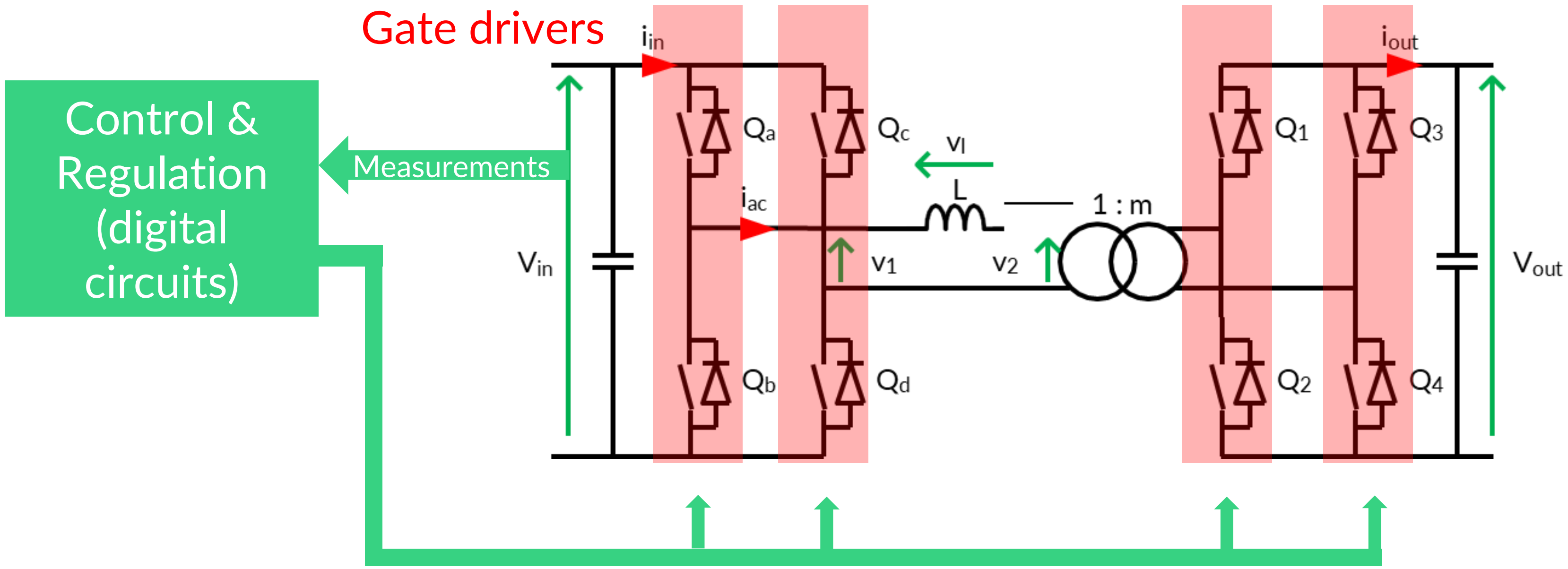
Basic architecture of DC-DC converter



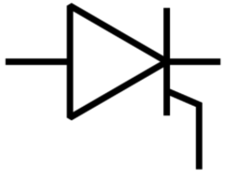




Families of components

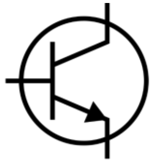
Three main categories of components to consider

Controlled turn-ON



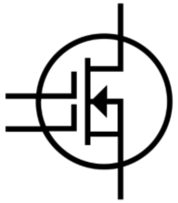
(Thyristors)

Current driven Components

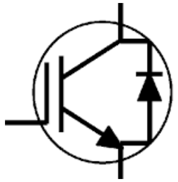


(BJT)

Voltage driven Components

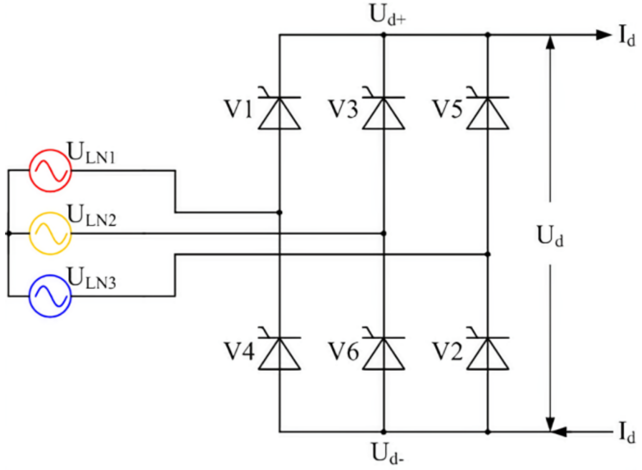


(Mosfet)



(IGBT)

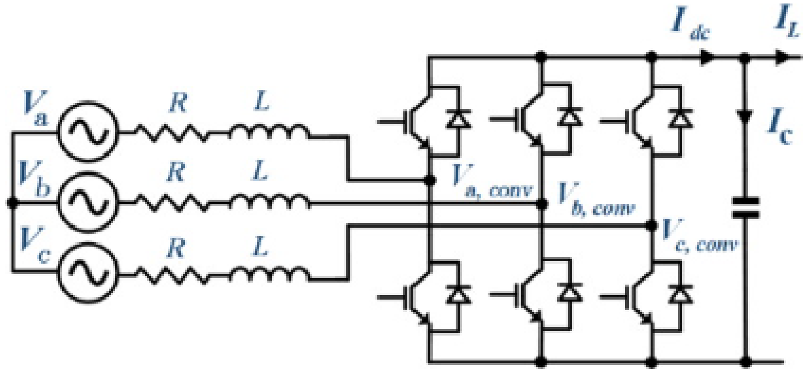
Line commutated converters (LCC)



(AC/DC)

(Spontaneous turn-off components)

Voltage source converters (VSC)



(Self-commutated components)

Technologies of components

Three main technologies on the market

	Silicon (Si) IGBT	Silicon Carbide (SiC) MOSFET	Gallium Nitride (GaN) MOSFET
Maxi. Voltage	6500 V	3300 V	1200 V
Maxi. switching Frequency	~ 3 kHz	~ 80 kHz	~ 1 MHz
Cost	++	+++	+
Typ. Applications	Automotive Power Conversion	Power Conversion	Automotive

(Power module)

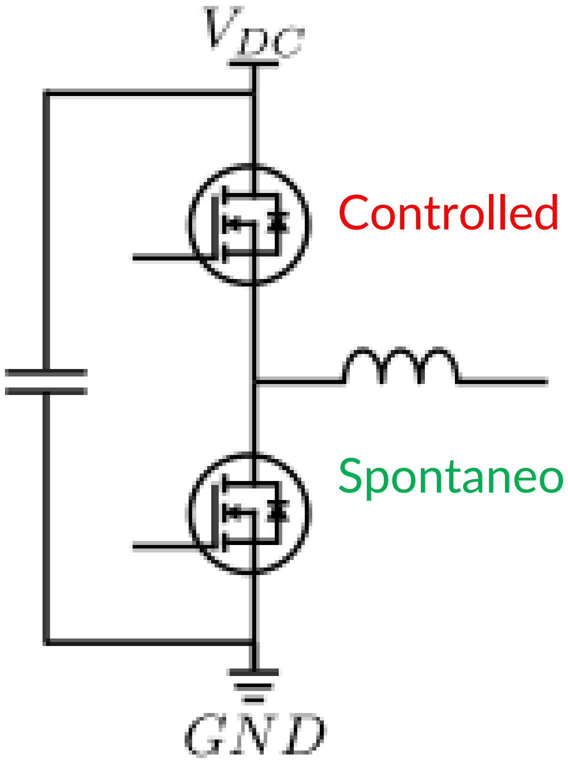
(Discrete case)

The switching cell

Basic structure of a power converter

- Half-bridge structure
- Switch + anti-parallel diode

Source connection of different types



Controlled switching : Mosfet (or IGBT)

Spontaneous switching : Diode

Package **62mm x 106mm x 30mm**

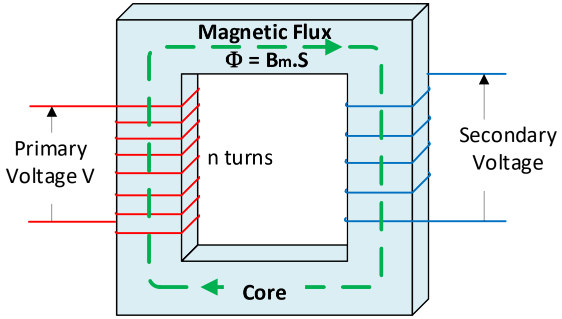
Monolithic component

Impact of medium frequency : compactness

Reduction of weight & size of passive components

- Boucherot formula :

$$\frac{V}{n} = 4.44 \cdot f \cdot B_m \cdot S$$

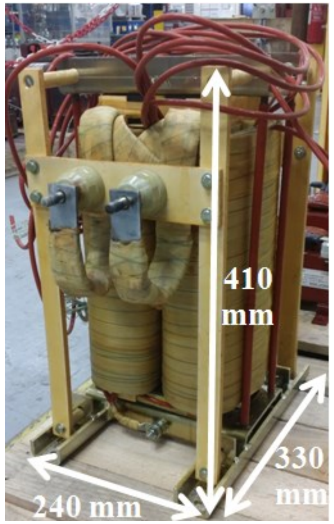


- The higher the frequency, the lower the magnetic cross-section

Example : transformer comparison 50Hz / 20 kHz

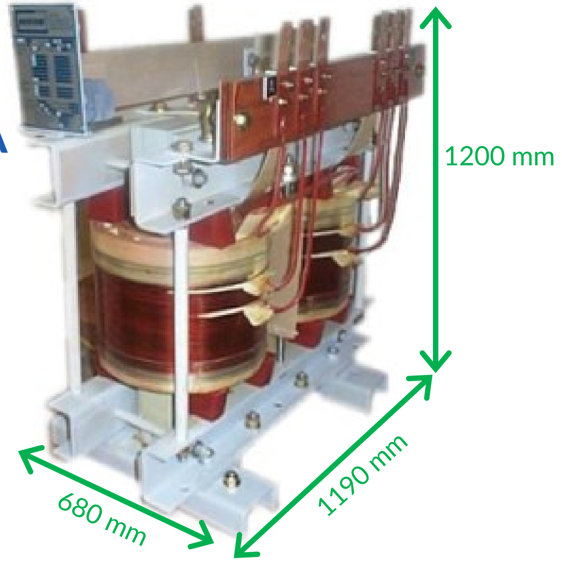
180 kVA
20 kHz

40 kgs

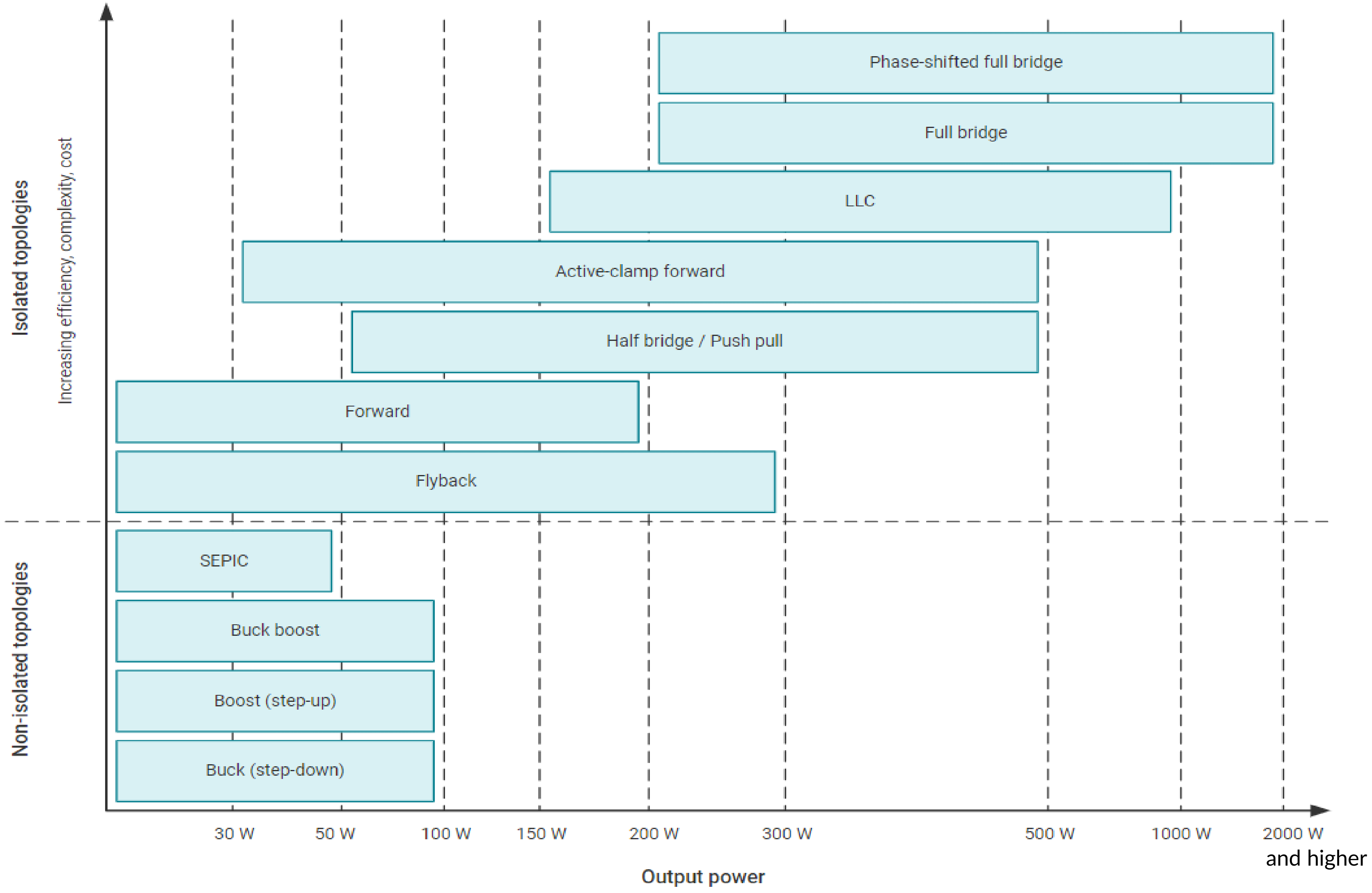


160 kVA
50 Hz

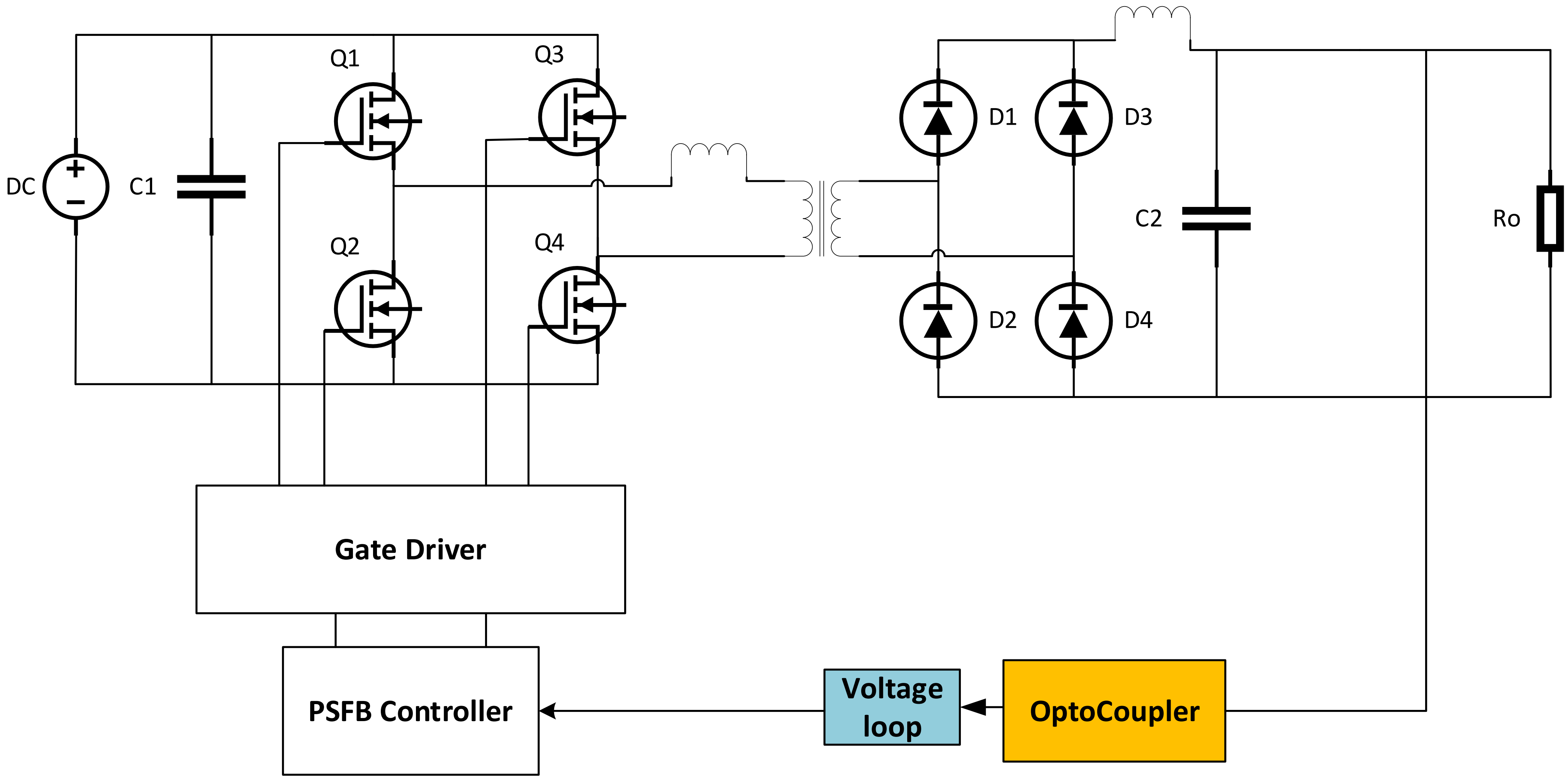
600 kgs



DC-DC Power converter topologies



DC-DC Power converter PSFB



Case study : linear PV Parc, OPHELIA project

© CNR

COMMUNIQUE DE PRESSE
31 Aout 2023

Avec le projet OPHELIA, CNR et ses partenaires Nexans, Schneider Electric, SNCF et SuperGrid Institute innovent et lancent un démonstrateur d'ombrières solaires sur la ViaRhôna

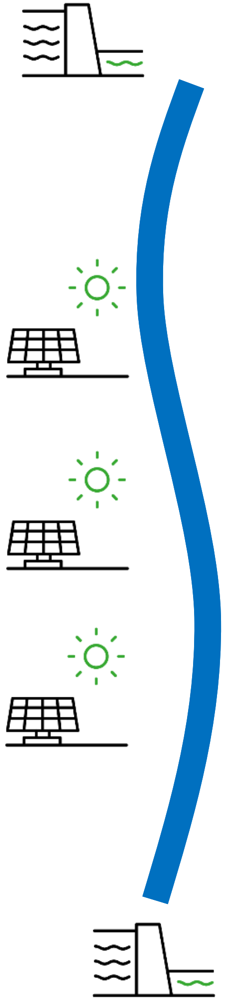
RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

ADEME
AGENCE DE LA TRANSITION ÉCOLOGIQUE

FRANCE 2030

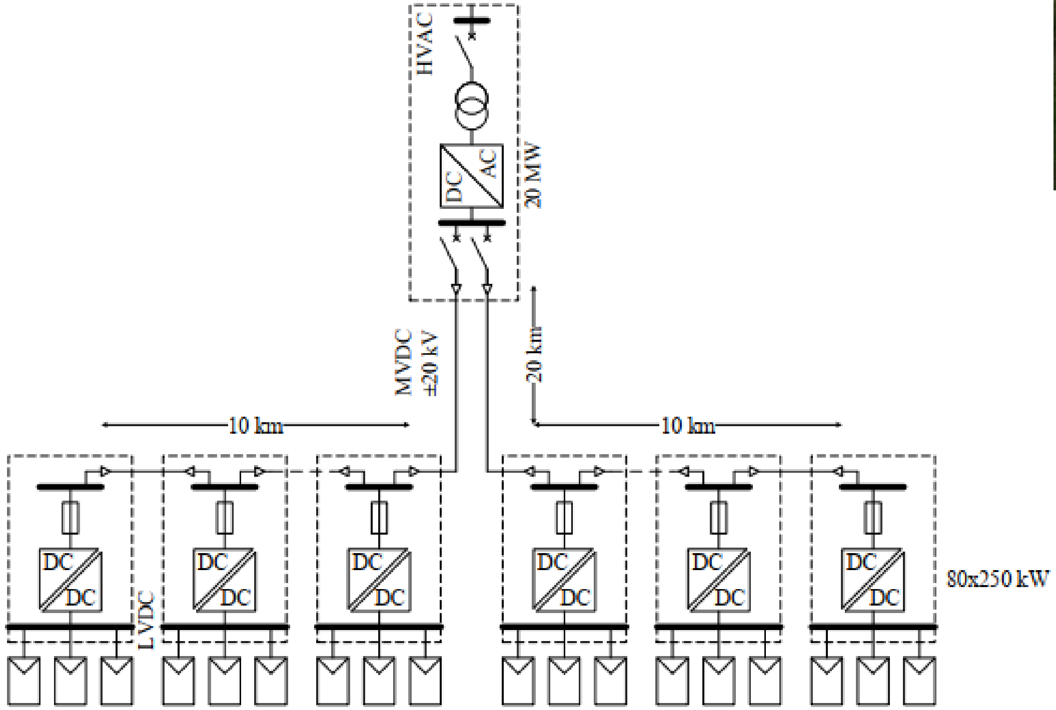
Case : Linear Photovoltaic Power Plant

case of: CNR



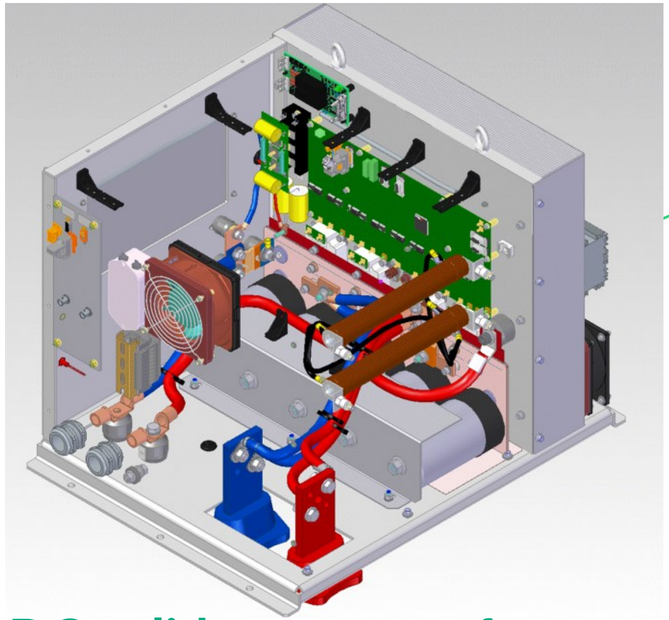
Main steps

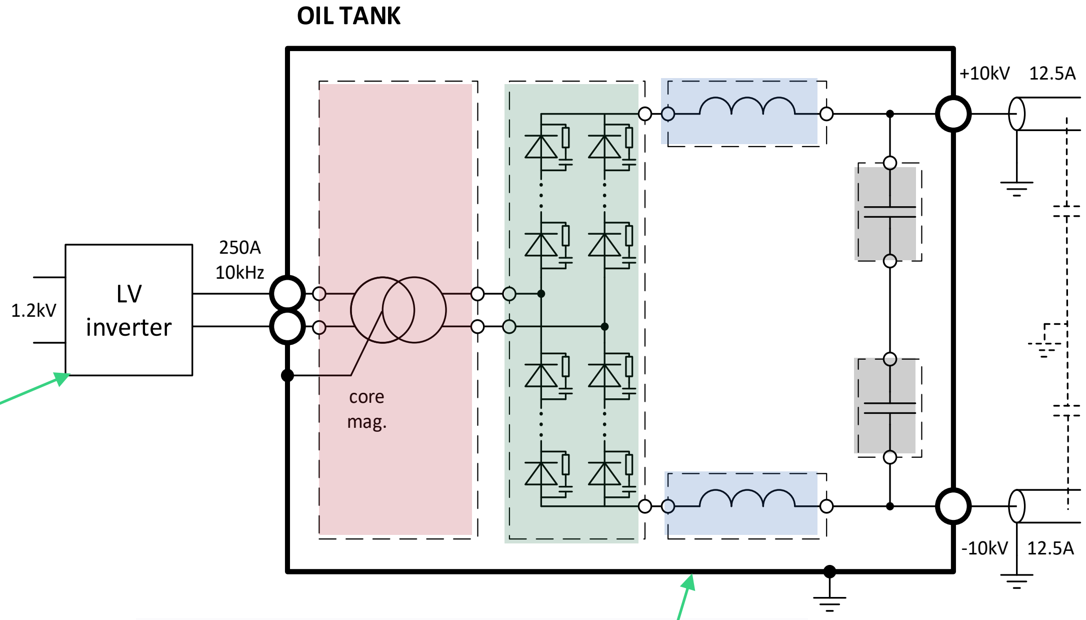
- Technical feasibility of the system
- Estimation of costs and key performance indicators
- Identification of technology locks
- Development of technology bricks and validation



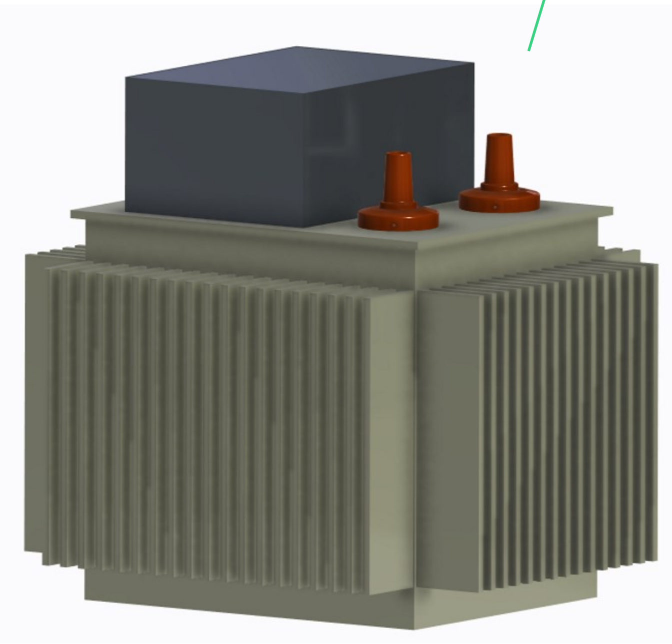
DC-DC Converter implementation

- **LV inverter 1.2 kV 250 kW**





- **DC solid state transformer with similar implementation as its AC equivalent : oil immersion**
  - Limits bulky MV connection number



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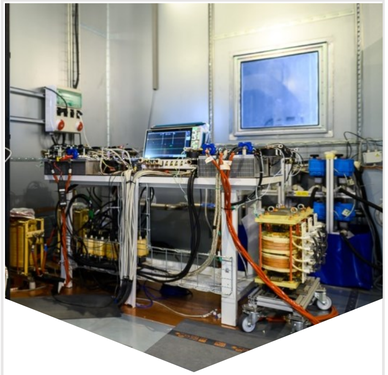
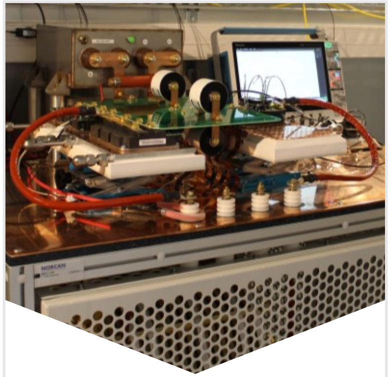
Conclusion

- **Medium voltage direct current (MVDC)**
  - Emerging technology
  - Involves passive and active components
- **SiC power module technology allows**
  - Size & weight reduction
  - High efficiency
- **Dedicated testing platform are needed**

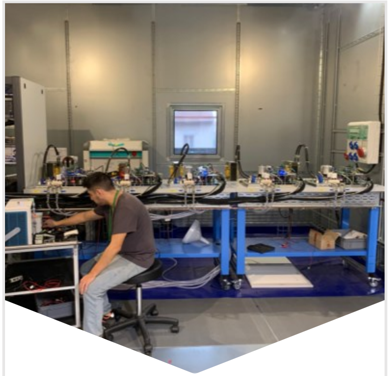


Power converters test benches

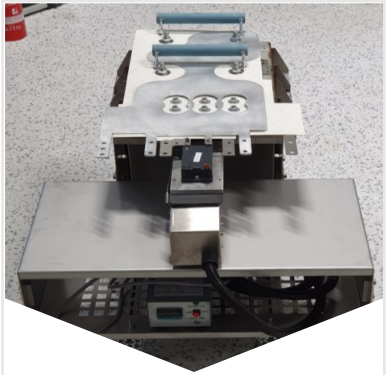
Medium Frequency Transformer Characterization



Semiconductor Device Characterization



Power Cycling Test Bench



Semiconductor reliability and robustness test benches

Thank you !