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DC NETWORKS FOR THE POWERING OF THE FCC

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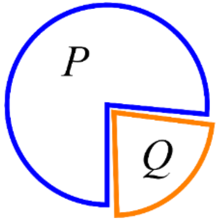
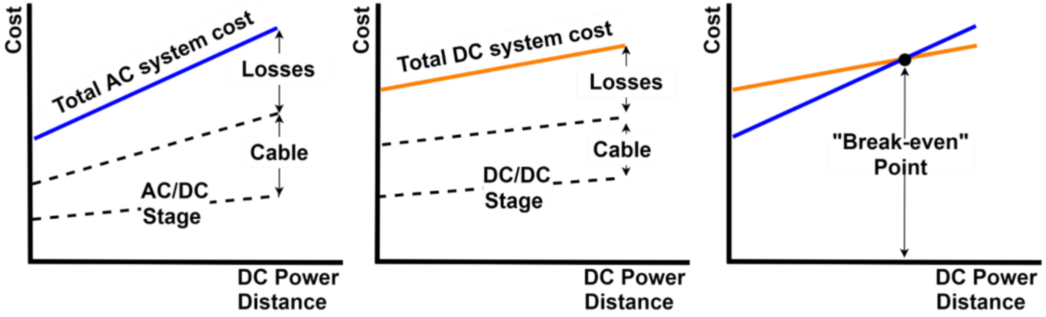
Why DC?



- ▶ No reactive power
  - → Lower constraints upon distance
  - → Transmission capacity increase
- ▶ Avoid high frequency effects (skin and proximity)



- ▶ Direct integration of DC sources
  - → Reduce converter stages
  - → Reduce system footprint
- ▶ Challenges
  - → Low reliability of power converters
  - → Difficult protection
  - → No DC standards

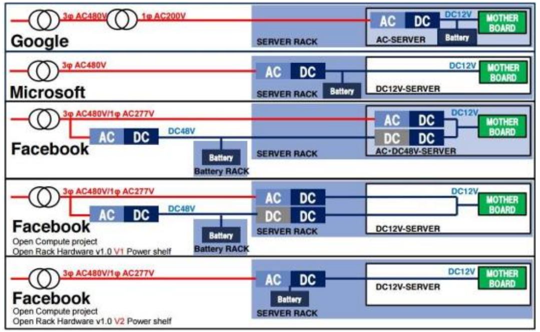
DC networks could help to further optimize the FCC electrical network

A Trend Towards DC

Bulk Power Transmission

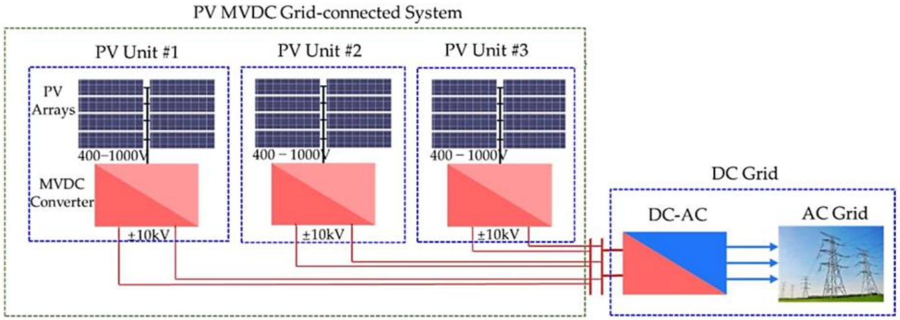
INELFE: HVDC Interconnection between France and Spain

Data Centers and Computer Infrastructure



Renewable Energy Integration

MVDC networks for PV/Wind energy farms



[1] H.Wang, Y.Zhou and others: Topology and Control Strategy of PV MVDC Grid-Connected Converter with LVRT Capability

- ► DC applications are a reality, however…
- ► There are still many technological challenges
- ► A pure DC-based network is nowadays not economically feasible

A Trend Towards DC: Technological Drivers

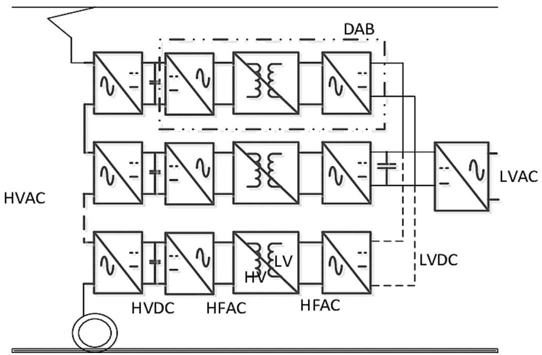
Modular Multilevel Converters converter (MMC)

- Voltage Source Converters: **Easy paralleling**
- Very modular = **high reliability**
- **High efficiency: >98%**

→ **MMC >> Thyristor-Based Converters**

→ **Cost MMC >> Cost Thyristor Converters**

High-Frequency Conversion technology (SST)



[1] V.Jakka, A.Shukla: Power Electronic Transformers in Smart Networks.

[2] ABB

- **Substitutes of transformers in DC networks**
- 50 Hz magnetics replaced by high frequency components: **reduction in footprint**

→ **Cost SST >> Conventional Transformers**

→ **Efficiency SST << Conventional Transformers**

→ **Footprint SST << Conventional Transformers**

Limitations of DC Networks

AC

400 kV Voltage Conversion 380 V

DC

HVDC Voltage Conversion 380 V

?

- Voltage conversions are difficult in DC, especially **High Voltage to Low Voltage**
- All power is managed by power converters: **lower reliability**
- Sensitivity to faults is higher in DC: **complex protection, costly DC breakers**
- Two possible uses of DC network:

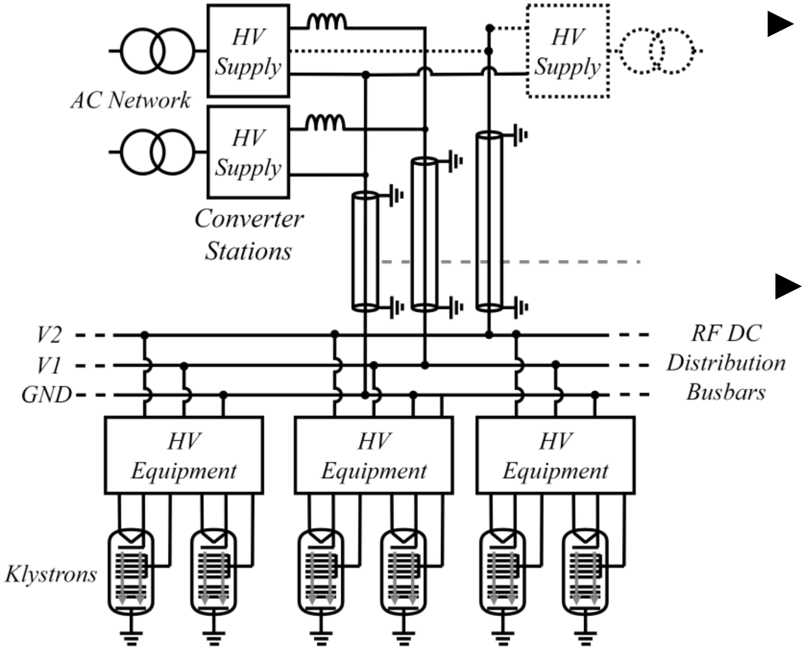
RF + High Voltage Transmission

DC Microgrids

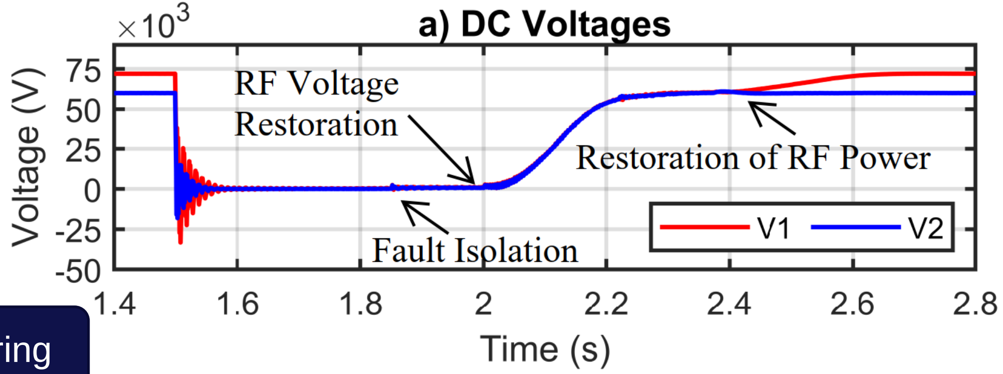
Supply of the RF Systems

HVDC Voltage Level LVDC

- Supply of a Common DC Distribution Busbar using Parallel-Connected MMCs



- MMC converters have been modified to cope with RF DC voltage requirements
  → DC Control range from **0 to 72 kV** or **60 to 72 kV**
  → Multi-port MMCs for **three terminal DC supply**
- Single bus connection is a concern regarding RF operation: **studies on fault ride-through have been performed**

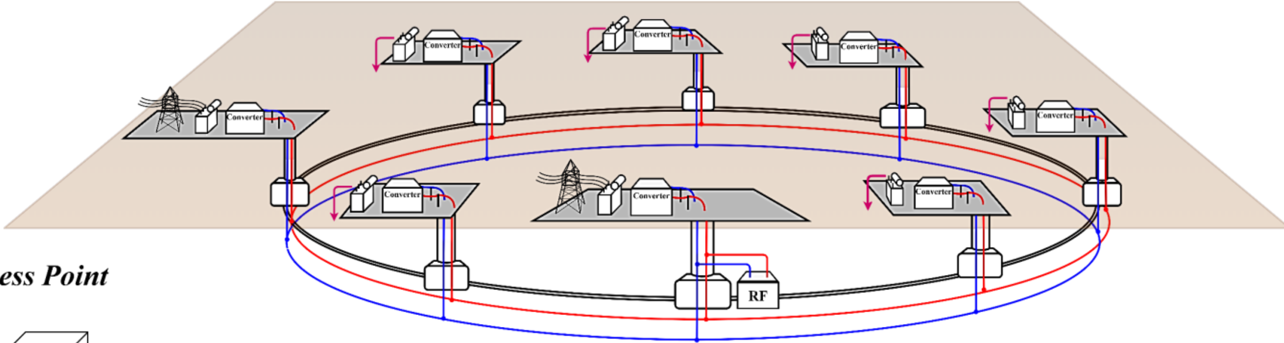


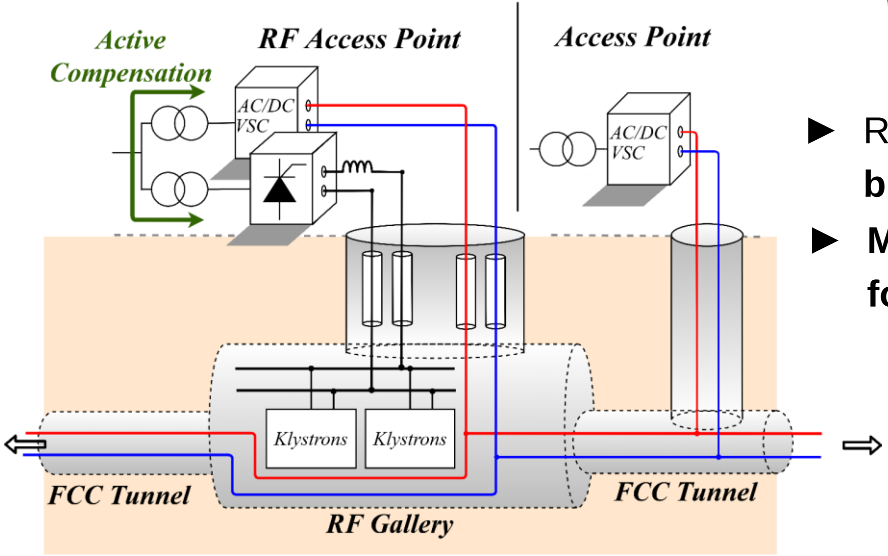
See Davide Aguglia's Presentation on RF powering

HV Transmission Network

HVDC Voltage Level LVDC

- **RF HVDC Powering Infrastructure could be used to transmit power in along the FCC ring**





- RF Supplied by **Thyristor Rectifiers (Poor Power Quality but lower cost)**
- **MMCs used as Active Filters and HVDC Rectifier (lower footprint than Static Var Compensators (SVCs)**
  - Lower cost of HV cables (two instead of three)
  - Lower transmission losses (no reactive power)
  - Better controllability (V-control, voltage glitches)

More Advantageous for FCC-hh

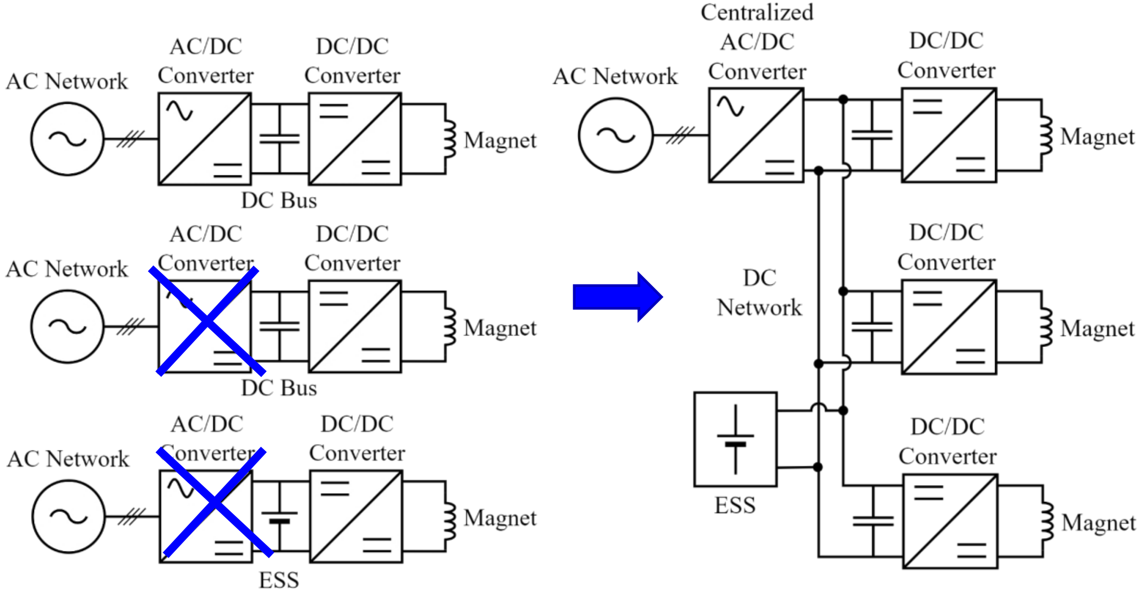
DC Microgrids for the FCC

HVDC Voltage Level LVDC

- AC/DC conversion stages can be centralized: single AC/DC Converter

- Reduction of the number of AC/DC conversion stages:
  → Higher efficiency
  → Lower footprint
  → Reduced complexity

- There are, however, several challenges:
  → Ensure Reliability
  → Grounding
  → Protection

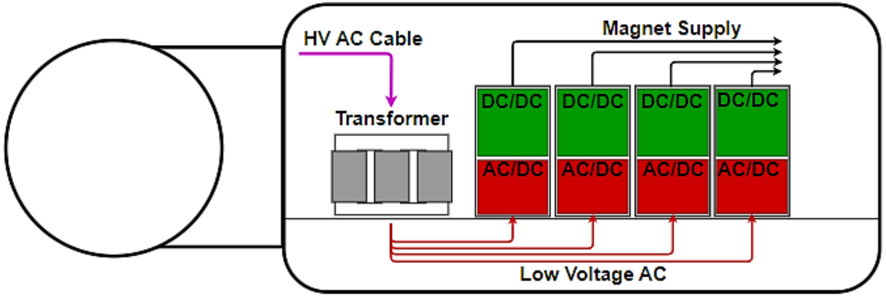


- **Same principle is applicable to other systems (i.e. experiments)**

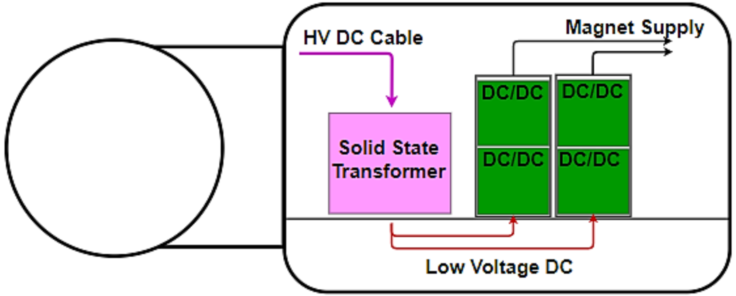
DC Microgrids for the FCC

- Optimization of the volume of the power converter alcoves

Conventional AC Solution



DC Solution



- AC/DC Converters centralized at the surface/technical galleries
- Solid State Transformers (SSTs) for Voltage Conversion
- Losses Transformer + Several LV AC/DC are higher than SST + HV AC/DC
- SST are very modular: easier transport, maintenance and scalability
- Comparative analysis with the AC baseline is difficult due to lack of expertise

Conclusions

"…There are still many challenges to be solved regarding reliability and cost…"

- **Extensive R&D is still required to fully exploit the potential of DC networks**

"… DC networks add an extra degree of freedom for the optimization of the FCC infrastructure…"

- **DC networks will be part of the global optimization tool**
- **Several systems susceptible to being converted to DC have been identified for the FCC**

"…What is missing nowadays?..."

- **Collaborate with other groups on the possibility of building their systems in DC (Computing, experiments…)**

Thank you
for your attention.