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

► 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)  High-Frequency Conversion technology (SST)

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

→ MMC >> Thyristor-Based Converters
→ Cost MMC >> Cost Thyristor Converters

► 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

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

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
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

► 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**

- AC/DC Converters centralized at the surface/technical galleries

**DC Solution**

- 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.