Power Control Issues in the Supergrid




Understanding the Objectives

- Sustainability
- Emissions reduction
- Petroleum independence
- Energy storage
- Integration with existing grid
- Remote generation siting

Why and Why Not Superconducting?

- Decrease losses
- Current density ~ 100x , *but notice that copper at 77 K also increases current density*
- Voltage tradeoffs are supported

Why NOT?

- Fault management and operational reliability
- Line taps
- Cryogenics
- Mesh current control

Transportation

- Transportation is not a logical use of H_2. Energy density per unit volume is too low for small-scale storage.
- For transportation, power control makes more sense with liquid storage, such as CH_3OH.
- Or could a power line in the road bed be an alternative?

Portable vs. Stationary Applications

- Portable
  - Energy storage
  - Energy density
  - "Conversion density"
- Stationary
  - Superconductor
  - → Devices (power Josephson??)
  - → Conventional (Si) at cryogenic temperature?
  - → Resistive fault current limiters

Distance

- Overhead HVDC, ±1500 kV
- Underground HVDC, with copper in LN2.
- Major advantage: relatively high impedance. Devices scale up from standard technology.
- HVDC grid architecture and control define a feasible research agenda. (Notice that conventional HVDC operates in a current-source mode.)
- ***From a power control perspective, superconducting lines do not add benefits compared to HVDC lines.***

“Ocean of electrons” concept

- Current sourced system (but this is conventional).
- BUT, given a broad electron flow device, only limited control is possible.
- Control devices (or at least asymmetries) are essential in the system.

Fundamental Challenges in HVDC

- Technology to support a true integrated HVDC grid:
- Circuit breakers
- Efficient conversion
- Tap interaction
- Dynamic optimization based on local data
- System-level wide-area real-time data
- Devices (for conventional HVDC, this becomes a scaling issue)
- Current vs. voltage architectures

Superconducting devices

- Conventional devices at cryogenic temperatures
- Full current capability (current density?)
- Circuit breakers, fault management, etc.

System Modelling

- Frequency-dependent models
- Full switch-based models
- Loss models
- Fault analysis, fault modalities
- Grounding models
- Simulation approaches

- Blackstart and large-scale dynamics?

Device Classes

- Semiconductors
- Non semiconductor switches
- Magnetic field devices (asymmetric)
- Variable inductance and inductance based flow controls
- Damping and energy absorbing

- Series tap: 10000 MOSFETs in parallel

Summary

- Superconducting system is extremely low impedance. Example: 25 kV, 100 kA. Base impedance is 0.25 Ω. Control elements in series, 0.1% of this or less. Devices with 100000 A capacity and 0.00025 Ω performance are not a logical extension of technology and do not imply a research agenda.
- Non-superconducting HVDC is much higher impedance. Example: 1500 kV, 2000 A. Base impedance is 750 Ω. Devices with 2000 A capacity and 0.075 Ω impedance exist today. Superconductivity does NOT reduce losses much compared to conventional systems, but a superconducting grid requires unknown new technologies while an HVDC grid does not.