Multi-Terminal HVDC Transmission

RD&D Needs

Green Energy Network Integration Workshop

Advanced Research Projects Agency

Department of Energy

December 13, 2010

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Atlantic Wind Connection

Atlantic Grid Development LLC

Topics to Be Covered

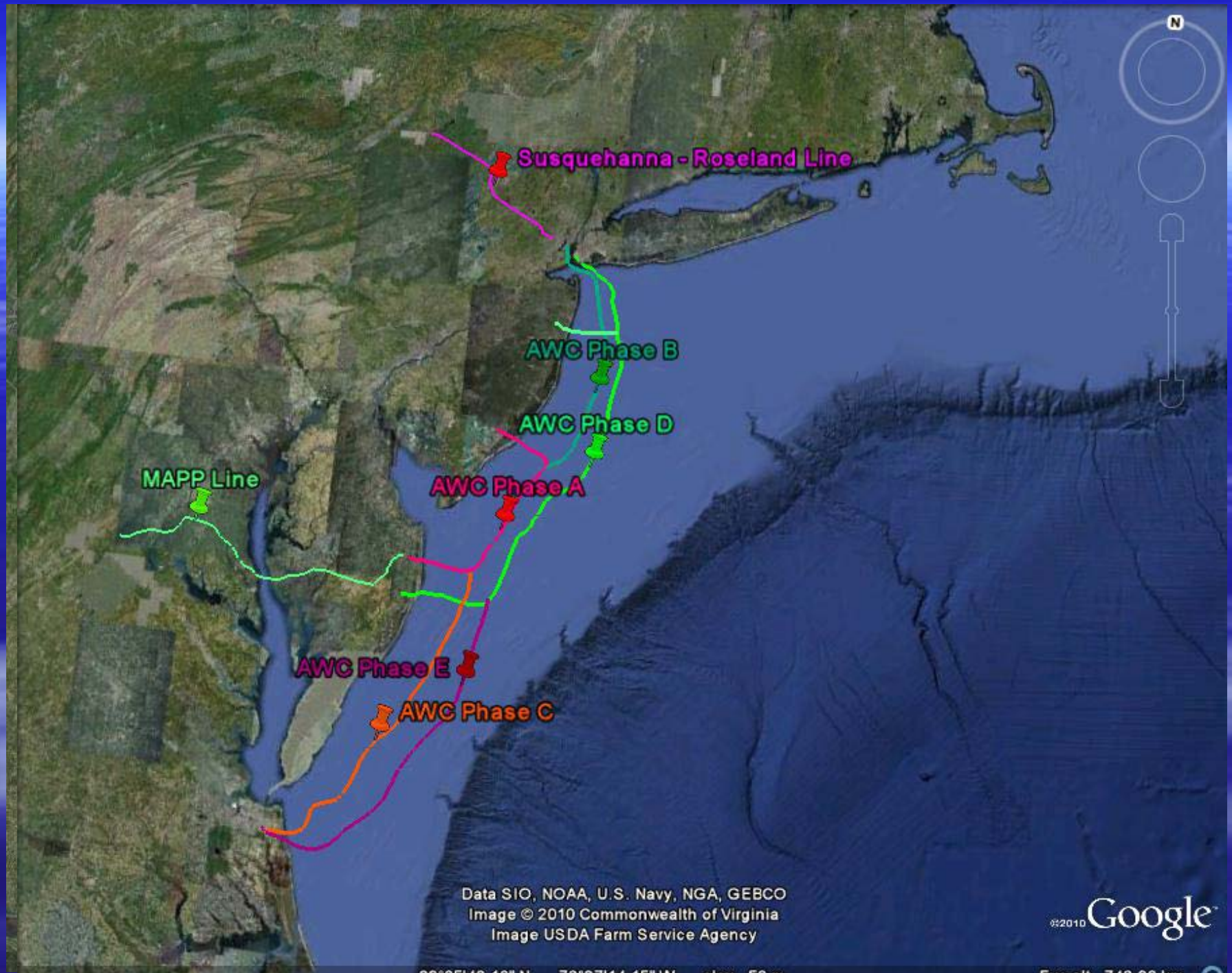
- Multi-Terminal HVDC (MTHVDC) Transmission
- Connection to Green Energy Network Integration
- The AWC Project
- RD&D Needs
- Conclusion

MTHVDC Transmission – A Broader View

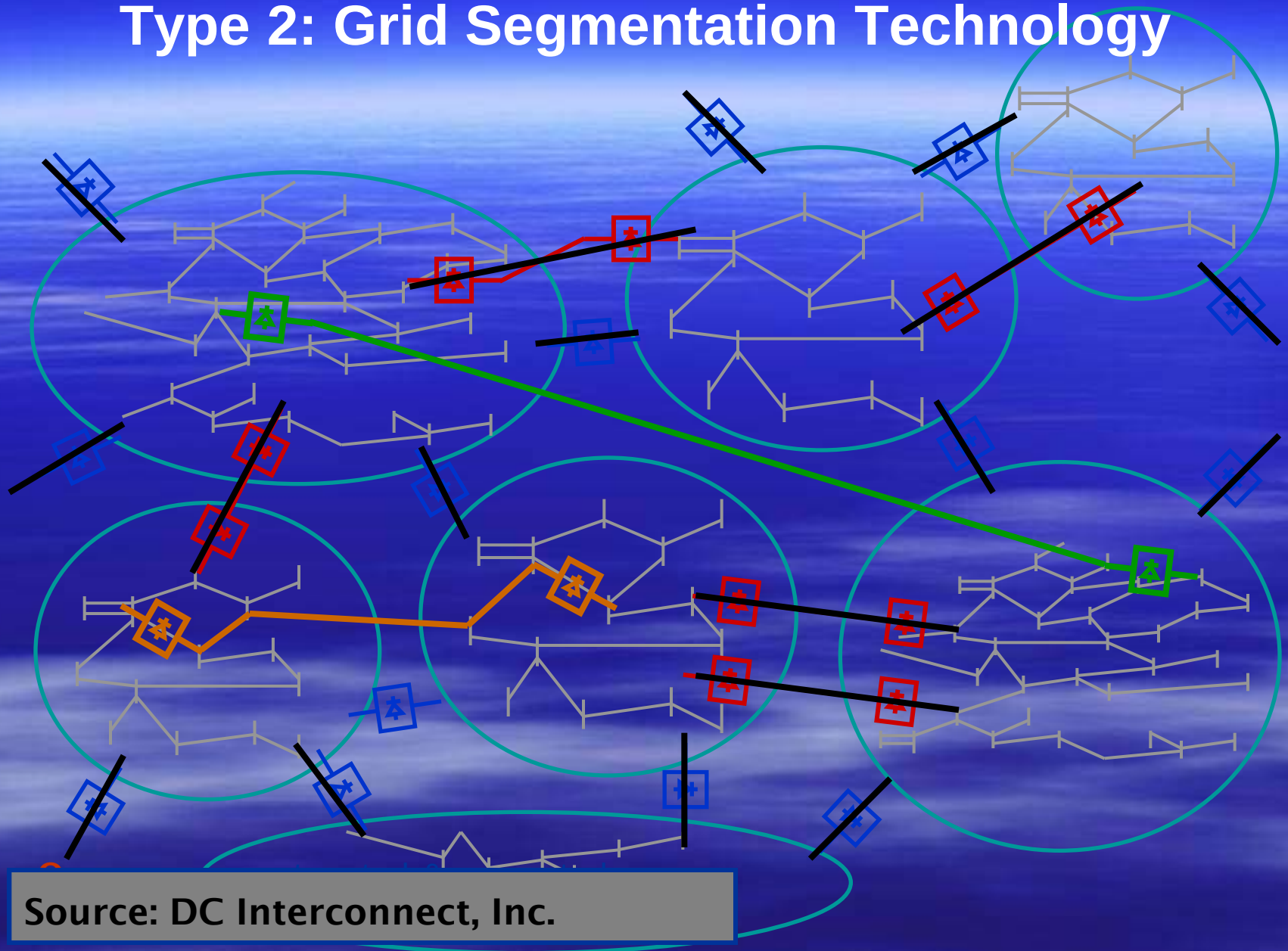
- Two types: Backbones and Distributed Systems
- Type 1: DC backbones
  - 1 or more spines linking 2 or more AC systems through ac/dc converters
  - Examples:
    - The Atlantic Wind Connection
    - The European Super Grid
- Type 2: Distributed DC systems
  - A set of DC links to enable asynchronous operation of AC networks
  - Examples:
    - Grid segmentation of the Northeast (DC Interconnect/EPRI Study)
    - Western Interconnect segmentation (DC Interconnect/BPA)

The Atlantic Wind Connection (AWC) Project

- Offshore multi-terminal voltage-sourced converter (VSCs) backbone
- Designed to facilitate least-cost development of 6000 MWs of offshore wind farms in federal waters off of NJ, DE, MD & VA
- AWC development funded by Google, Good Energy & Marubeni Power
- Project developer: Atlantic Grid Development, LLC (AGD)
- Development spearheaded by TransElect
- Optimal power flow scheduling over 2000-MW transfer capability
- Adds 2 independent transmission circuits into PJM
- First phase energization: 2016


Susquehanna - Roseland Line
AWC Phase B
AWC Phase D
MAPP Line
AWC Phase A
AWC Phase E
AWC Phase C
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2010 Commonwealth of Virginia
Image USDA Farm Service Agency
©2010 Google
39°05'43.18" N 73°27'14.15" W elev -53 m
Eye alt 743.96 km

Type 2: Grid Segmentation Technology



Source: DC Interconnect, Inc.

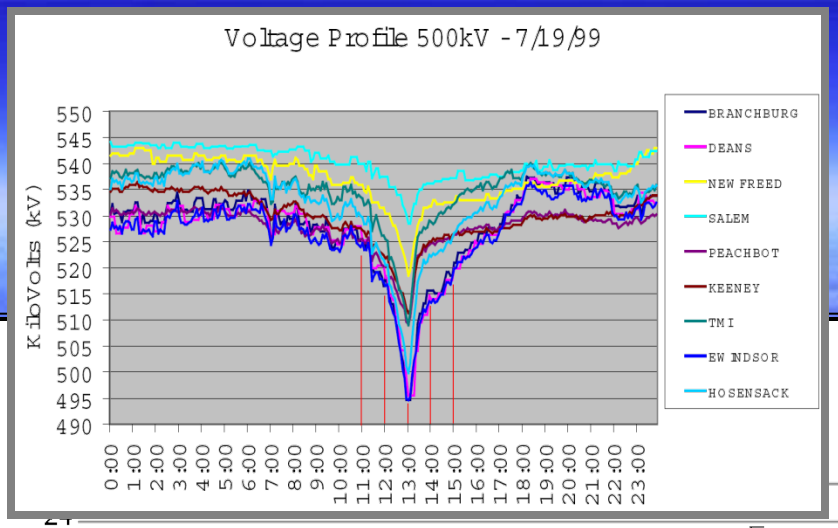
Connection with Green Energy Network Integration

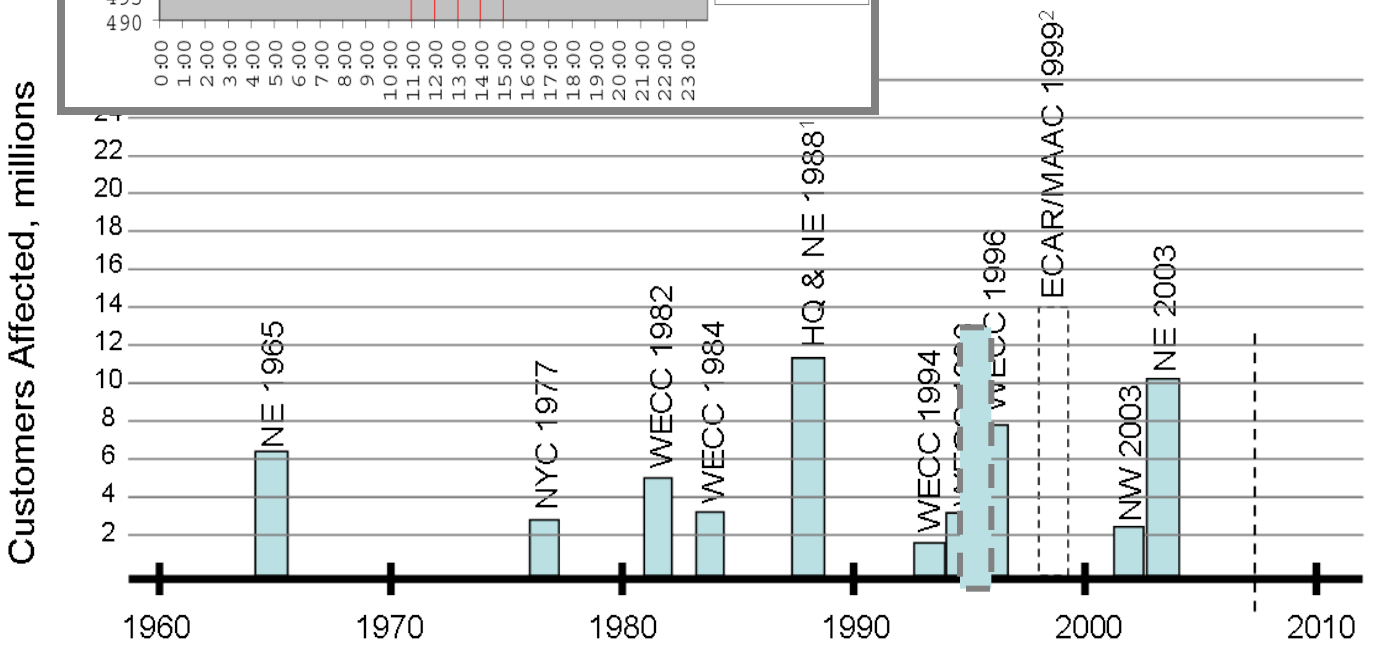
Multi-Terminal HVDC Transmission will:

- **Enable efficient interconnection of high-quality renewables**
- **Avoid/resolve environmental & aesthetic issues of siting large clusters of wind farms in state and federal waters**
- **Virtually ensure access to enough offshore resources to meet RPS needs and beyond**
- **Common goal with Green Energy Network Integration: Minimize the cost of delivered green energy**

Minimizing the Cost of Delivered Green Energy

- Enable capture of economies of scale
- Take advantage of reliability benefits of MT HVDC transmission
- Combine MT HVDC transmission advantages with the zero fuel-costs of the dominant sources of green energy to optimize market operations
- Reduce pressures to develop new rights of way





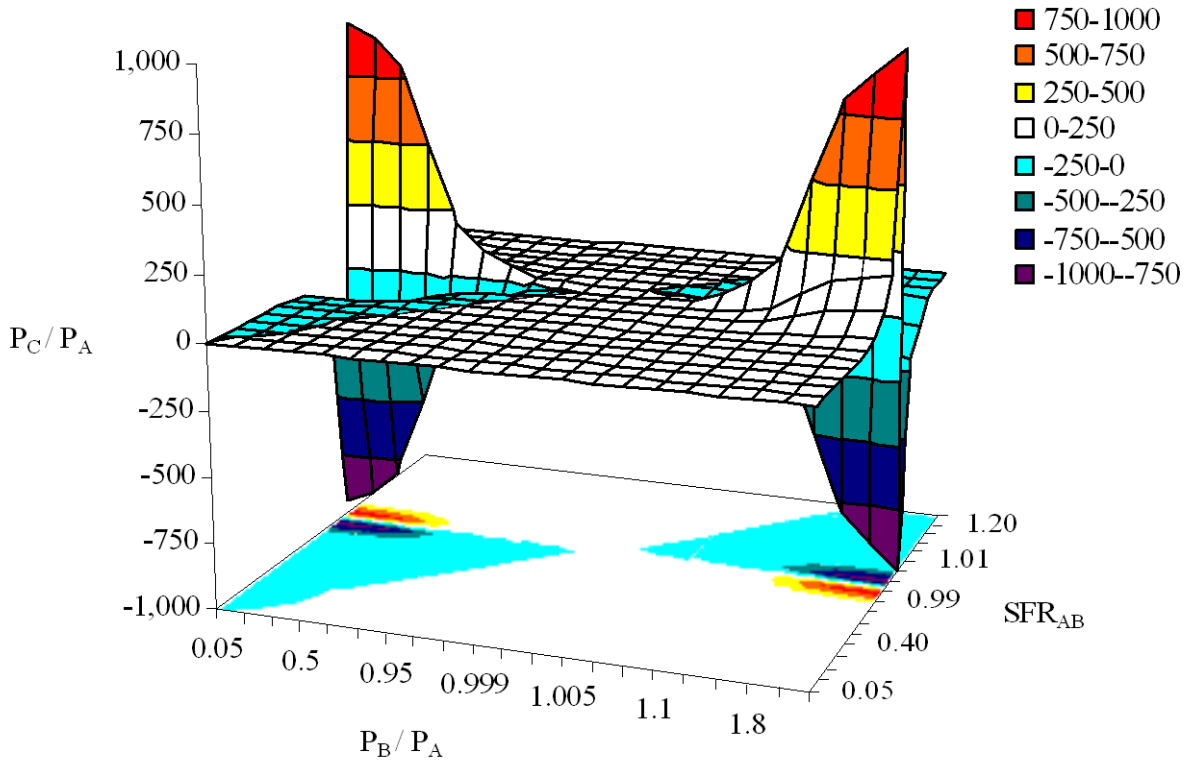
Notes:
1 Three events in New England, one in Hydro Quebec.
2 No large-scale customer outages resulted, but the multiple close calls In this summer period are legend and should be recognized.

The outlook for reliability is not good

Atlantic Grid Development LLC

Nodal Price Sensitivity to Bidding & Generation Distribution Factors

"Give me a lever long enough and a fulcrum on which to place it, and I shall move the world" *Archimedes*



Source: Rumla, Inc.

Multi-Terminal HVDC Transmission
RD&D Needs

- The recommendations are based on our experience with the AWC Project

- The RD&D needs fall under two categories:
  - Technological recommendations
  - Regulatory advances

Technology RD&D Recommendations

- VSC design standards, including control systems, to promote interoperability across manufacturers
- Interconnection standards for wind farms connecting to offshore HVDC hubs, including connecting voltages and wind turbine performance (e.g., ride through)
- Electronic DC circuit breaker development as a path to larger capacity HVDC backbone systems
- Offshore HVDC converter platform optimization and modularization to promote cost reduction

VSC Design Standards RD&D Recommendations

- We found interest in both U.S. and Europe in developing common converter design standards
- Manufacturers & advocates also expressed similar interest
- As a multi-phase project, we are very keen on assuring interoperability for AWC system components
- Establishing common standards for VSCs will encourage similar development for cable systems; increasing certainty for investment in local cable manufacturing capability

Recommendations for Regulatory Improvements

- Develop – if needed – NERC reliability criteria specific to multi-terminal HVDC systems – but we can live with harsh criteria developed for ac systems
- Accelerated development of intra-RTO planning and cost allocation criteria for multi-terminal HVDC projects – the AWC is an intra-RTO project
- Accelerated development of inter-RTO planning and cost allocation criteria for multi-terminal HVDC projects

For More Information

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