Investigating Mode Transitions & Power Management in Medium Voltage DC Networks

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Microgrid Development Needs

Fundamental Requirements of Microgrids

- Capability of Operating in Islanding and/or Grid Connected Modes with High Stability.
- Mode switching with minimum load disruption and shedding during transitions.
- After a transition, stabilize in a certain amount of time.

Technical Challenges of Microgrids

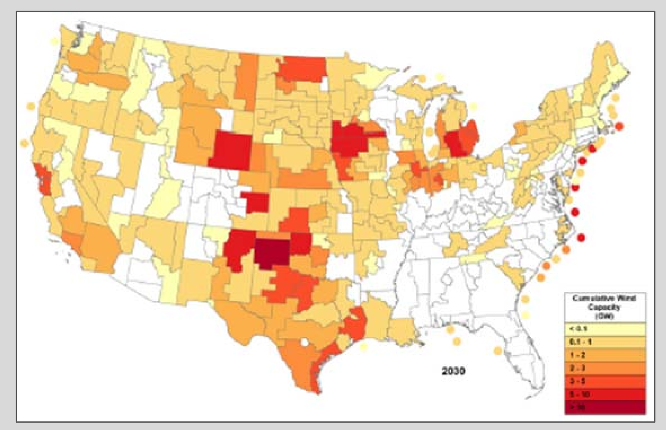
- Operation modes and transitions that comply with IEEE 1547.
- Control architecture and communication

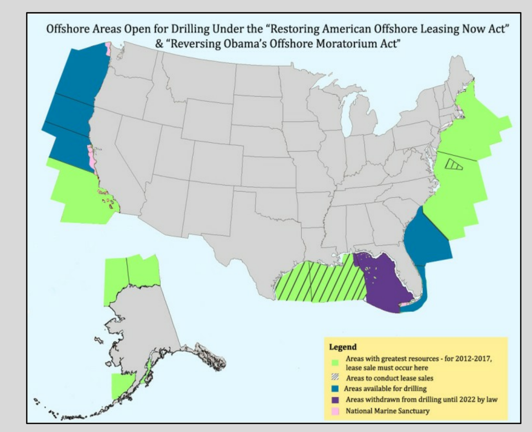
Research Challenges of Microgrids

- Operational inverter improvements (harsh environment design, robust operation during fault conditions, volume and weight reduction).
- Integrated storage inverter & direct medium voltage inverter design.
- DC microgrid subsystems.
- Protection is also one of the most important challenges facing the deployment of microgrids.

Offshore Wind Generation Trends

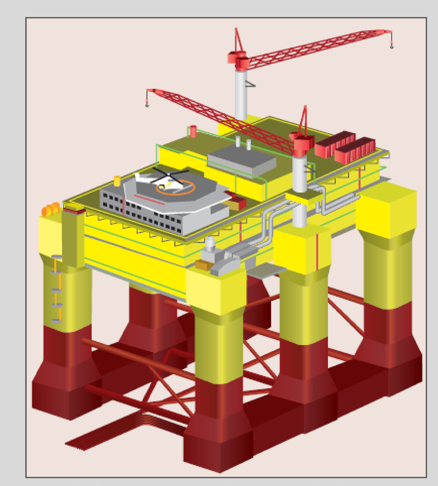
- The U.S. Department of Energy, through FOA-414, has found great interest in exploring the integration of *offshore* wind and has funded a team (including Pitt) to determine the optimal location for placing large wind turbines around the U.S. perimeter.


Onshore and Offshore Wind Deployed by 2030


Offshore Areas Open for Oil Drilling

- The directions that many manufacturers are exploring with offshore technologies to harness and transmit electric power provides further encouragement that the direction towards offshore is viable.


Wind Power Offshore Substation (WIPOS)
Siemens Offshore Design


3D Model of HVDC Hub for Dolwin 2 Project
ABB Offshore Design

Industrial Facility: Offshore Oil Drilling Platform

- Industrial facilities, like the oil platforms, experience three major types of power quality obstacles.
  - ✓ **Voltage Sags** are caused by motor starting, short circuits, fast reclosing of circuit breakers. Issues interrupt adjustable speed drives which are the sensitive loads in the facility.
  - ✓ **Transient Overvoltages** are caused by energizing filter banks and transformers.
  - ✓ **Dynamic Overvoltages** are a result of resonant system effects due to transformer energizing (duration is longer)
- Power quality is degraded due to harmonic currents produced during the *conversion from AC to DC for VFDs.*
- Mitigation techniques include active and passive filters and multi-pulse drives requiring additional space and increased platform weight.

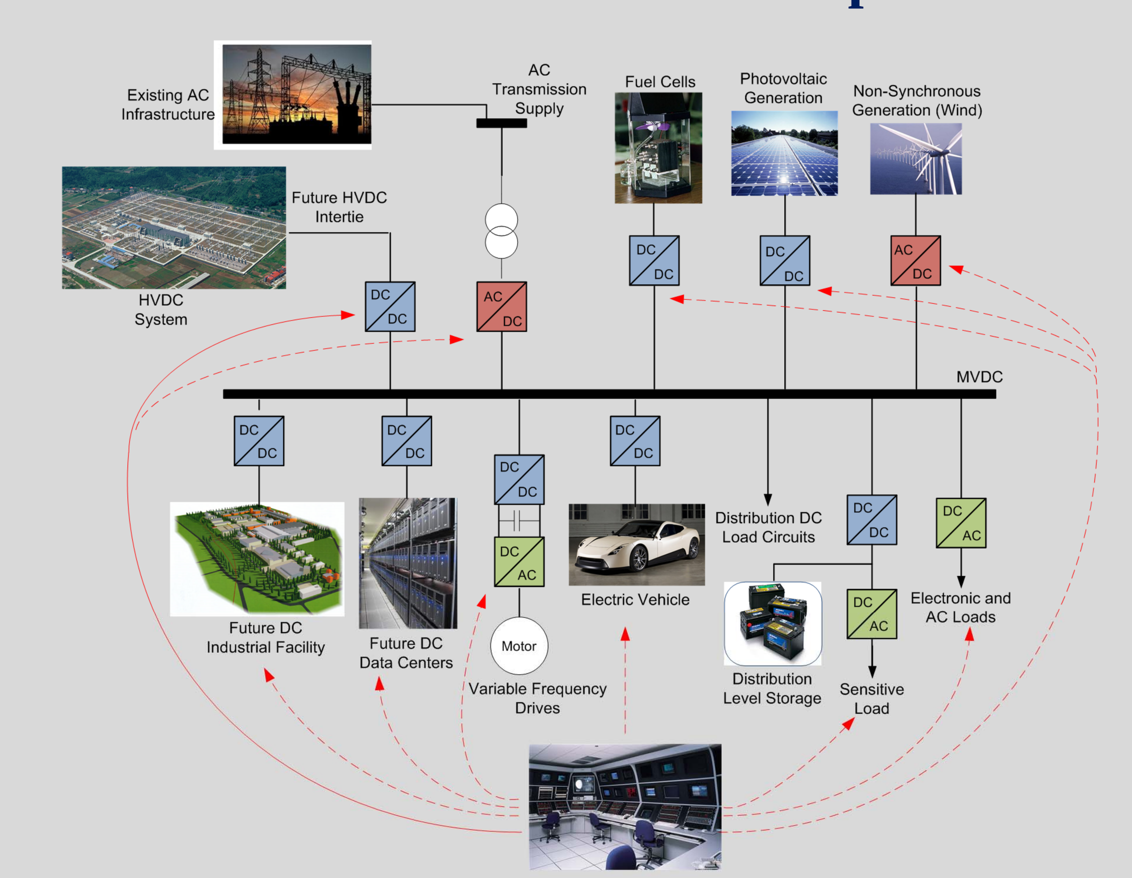
Innovation and Creativity with DC Backbone

- The off-shore oil drilling platform is an opportunity for a more innovative application while taking advantage of the offshore wind turbine power generation locally.
- A voltage controlled DC backbone *might* minimize the harmonic current injections with one less power conversion stage seen by the VFDs.
- Mode transitions (adapted from Microgrids) in generation (Wind / Diesel Generator / Utility Feed) will need to be considered to supply seamless, continuous power to the platform.


Offshore Oil Drilling Facility

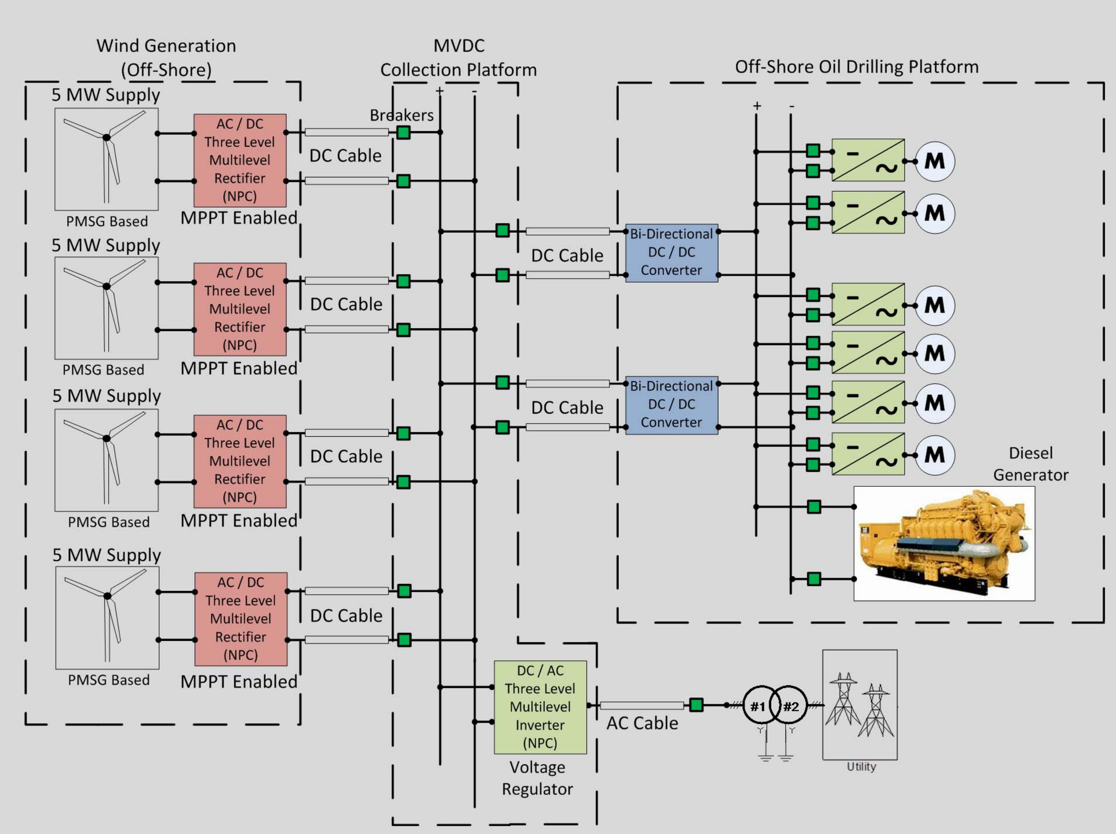
Medium Voltage DC Concept: Theory to Application

General MVDC Concept



- General concept of DC collection system showing future generations and loads.

MVDC Backbones within DC Microgrids

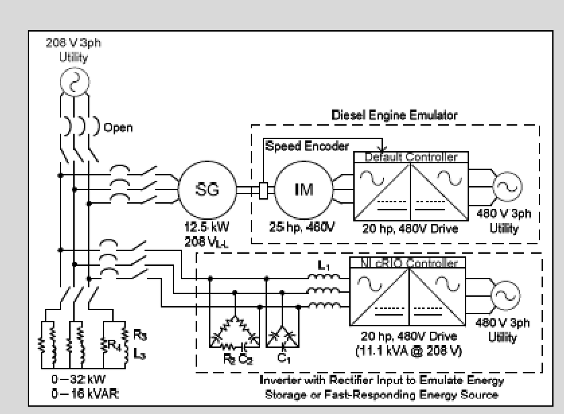


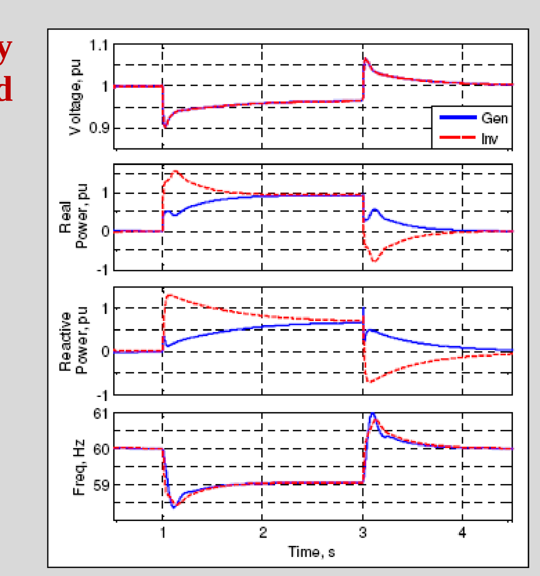
- Local wind power generation to serve offshore oil drilling platform with backup from utility feed and diesel generation.

Specific Application Obstacles Under Investigation

Transient Load Sharing in Mode Transitions

- **Power electronics supply majority of the power during grid connected to islanded transition.**





Paquette, A.; Reno, M.; Harley, R.; Divan, D.; "Transient Load Sharing Between Inverters and Synchronous Generators in Islanded Microgrids," *2012 Energy Conversion Congress and Exhibition, [To Appear]*

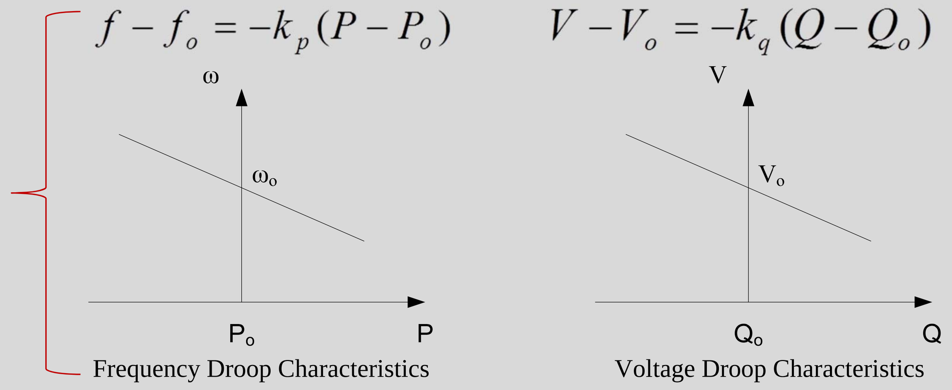
Handling Various Mode Transitions

Grid Connected to Islanding
Grid Connected, Internal Fault Ride-Through
Islanding to Grid Connected
Grid Connected, Grid Fault Ride-Through

Parallel Converter Control Differences

Parallel Inverter System

$$f - f_o = -k_p(P - P_o) \qquad V - V_o = -k_q(Q - Q_o)$$



Frequency Droop Characteristics — Voltage Droop Characteristics

Parallel DC/DC Converter System

$$V_{o,\max} - V_o = R_o I_o$$

DC System
Is the control easier or more difficult with less variables?

Power Management Strategies Utilizing HVDC