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A Study on the Impact of Replacement of AC Transmission Lines by VSC-HVDC

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Motivation behind HVDC

- Growing energy demand:
  - Difficult to build new line corridors.
  - Need to **increase the utilization of the existing corridors.**
- Manage inertialess intermittent renewable generation and increase system resilience:
  - Need to **increase controllability and flexibility.**

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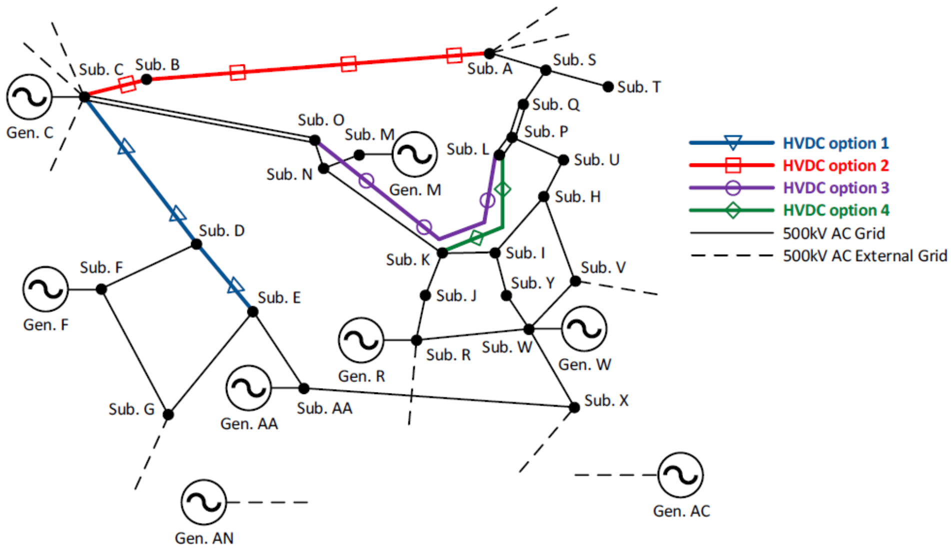
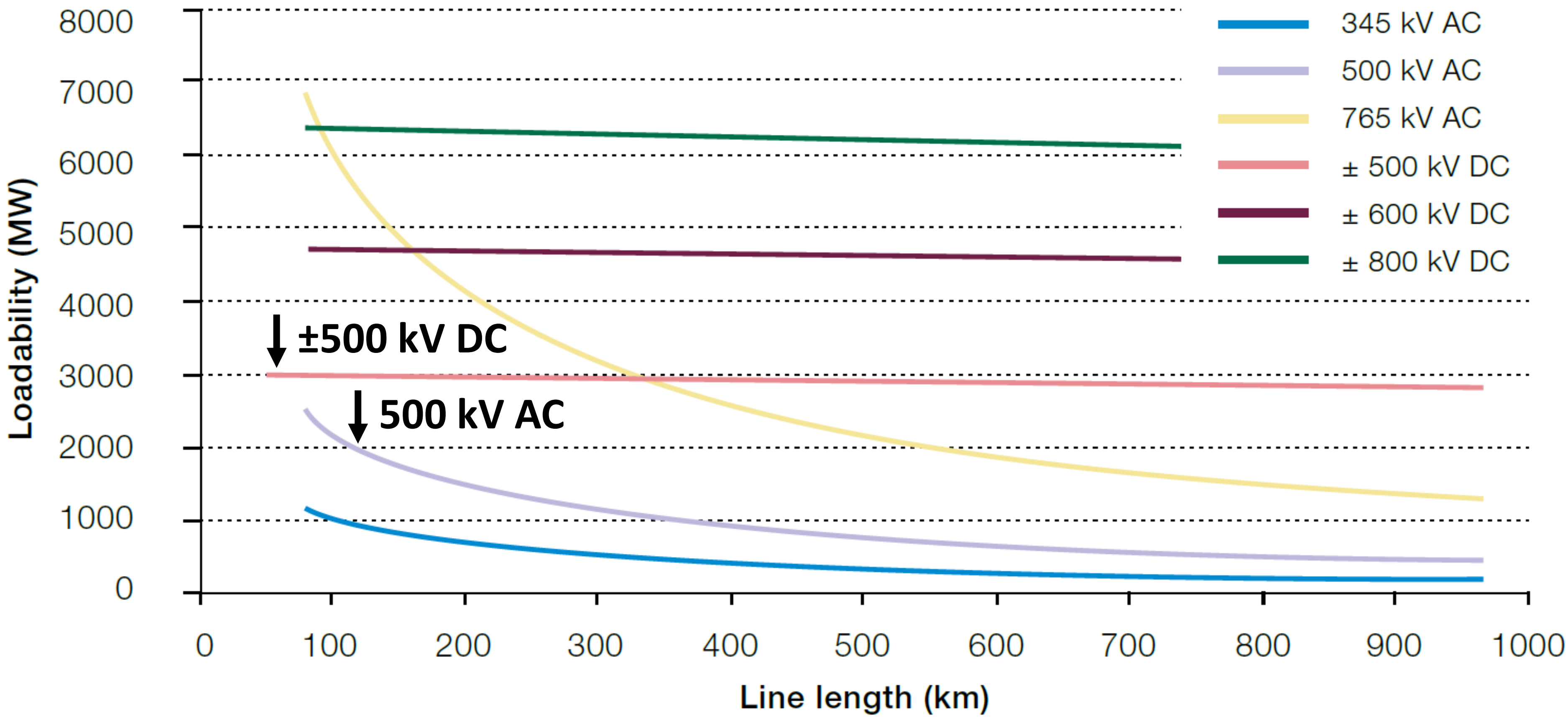
Dominion Energy's vision for this project

- To develop technical competency to expand into areas that may be advantaged with HVDC.
- To build upon expertise using power electronics to control energy flow.
- To explore possibilities of a potential national HVDC overlay network.



- **Four alternative HVDC link options have been considered.**

HVAC versus HVDC Transmission Lines



LCC versus VSC technology – Why did we pick VSC?

Line Commutated Converter (LCC)

- **Early 1950's**
- **Thyristor** is active component in valves.
- **Cannot be switched off**, automatically ceases to conduct when voltage reverses.
- Allows for **5,000A**

Voltage Source Converter (VSC)

- **Late 1990's**
- **IGBT** is active component in valves.
- **Can be switched off** with a control signal, fully controllable.
- Allows for **2,000A**
  - **4,000A** in near future.

LCC versus VSC technology – Why did we pick VSC?

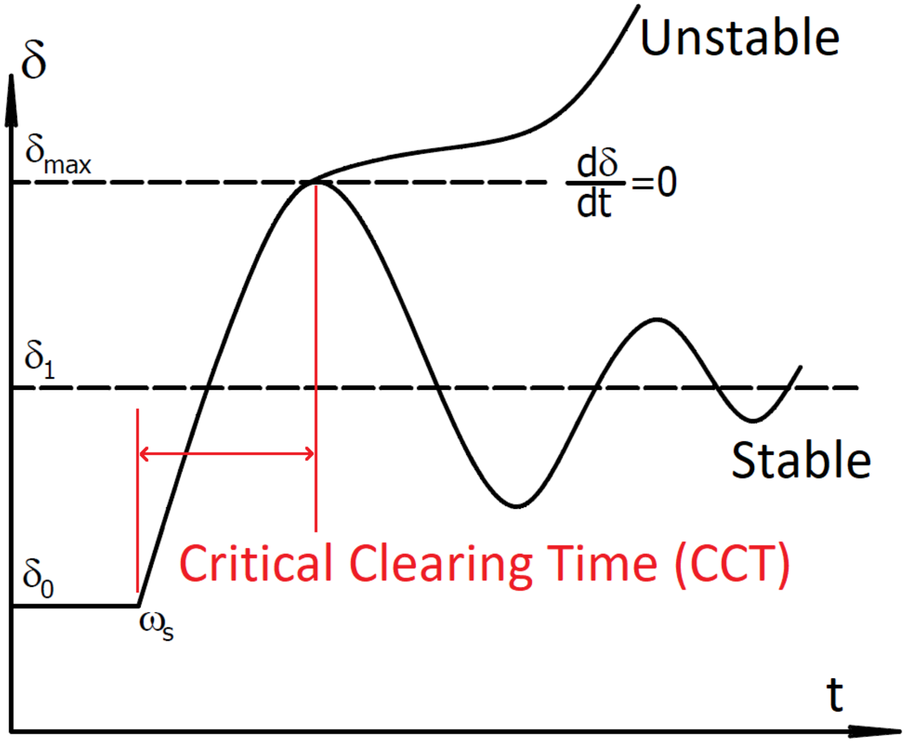
	LCC	VSC
Generates significant harmonic distortion	Yes, AC and DC filters required	No, less filters required
Footprint (acres)	5.93 for 600MW	3.71 for 1,200MW
Requires converter transformers	Yes, due to continuous DC voltage stress	No, if symmetric bipole
Oscillations damping capability	No	Yes
Black-start capability	Yes, requires additional equipment	Yes
Short-circuit level restriction	Yes	No
Bidirectional power transfer without polarity reversal	No	Yes

VSC-HVDC Model

- PSS/E has two VSC-HVDC built-in models: HVDCPLU1 and VSCDCT.
- Two control schemes are available on the AC side:
  - Active Power–Power Factor (**P-PF**) / Active Power–Voltage (**P-V**).
  - There is no provision for auxiliary signals like damping controllers.

Transient Stability Analysis (TSA)

- Objective is to maintain synchronism under large disturbances.
- CCT is the metric to assess stability margin.
- Importance of TSA:
  - ➢ HVDC modifies coupling between generators.
  - ➢ HVDC has the capability to provide voltage support.



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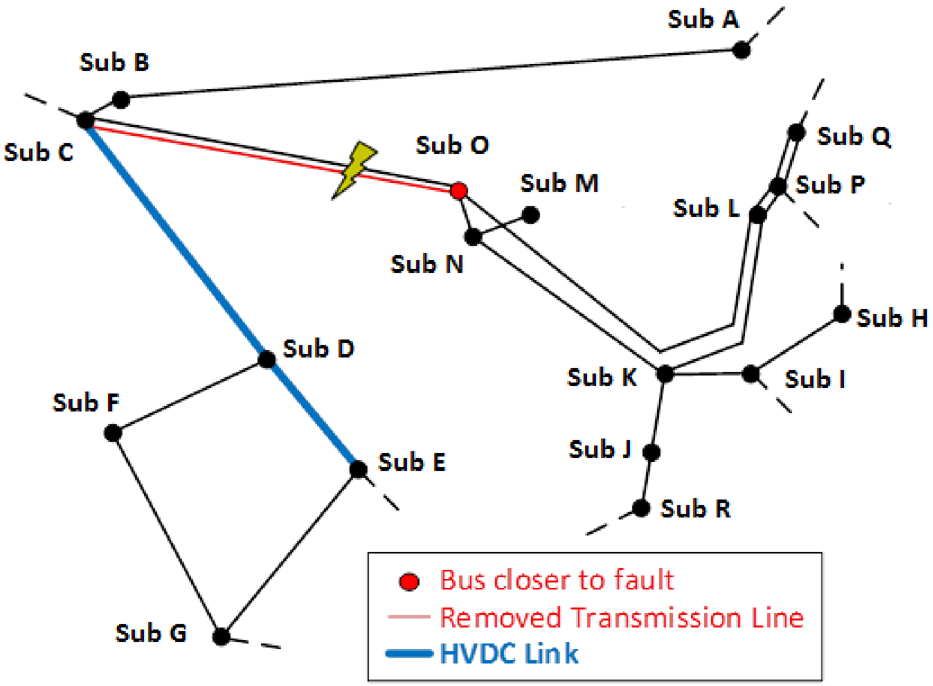
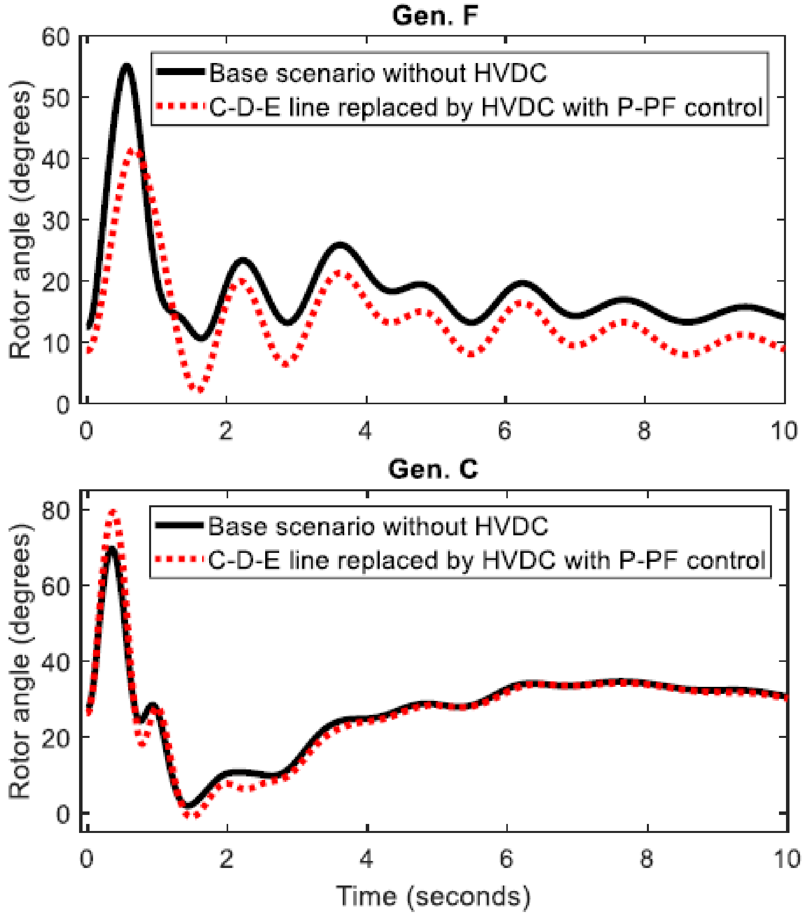
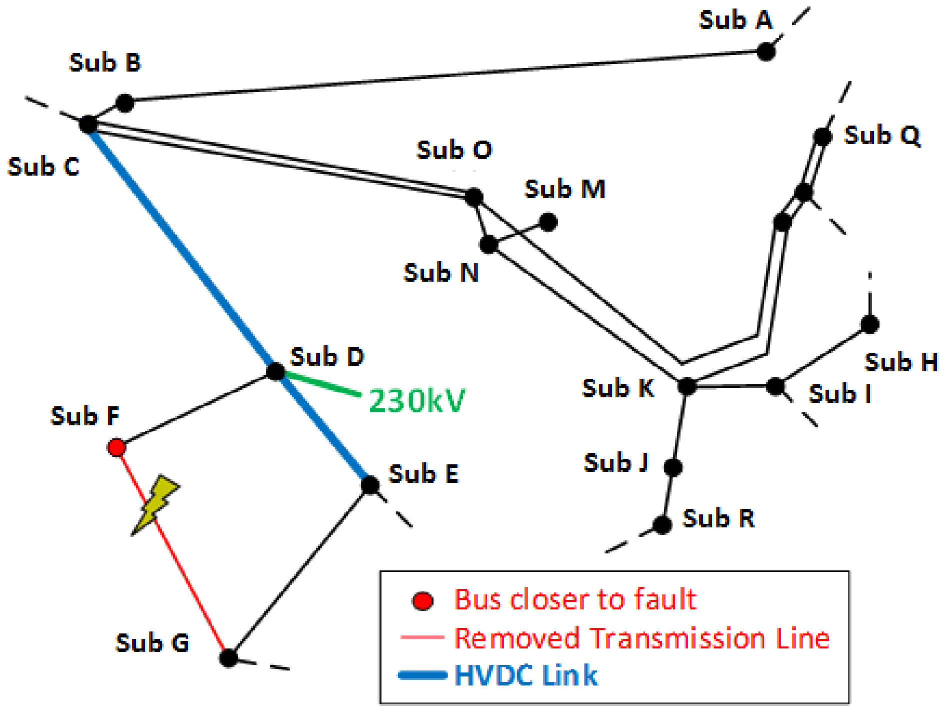
HVDC option 1:

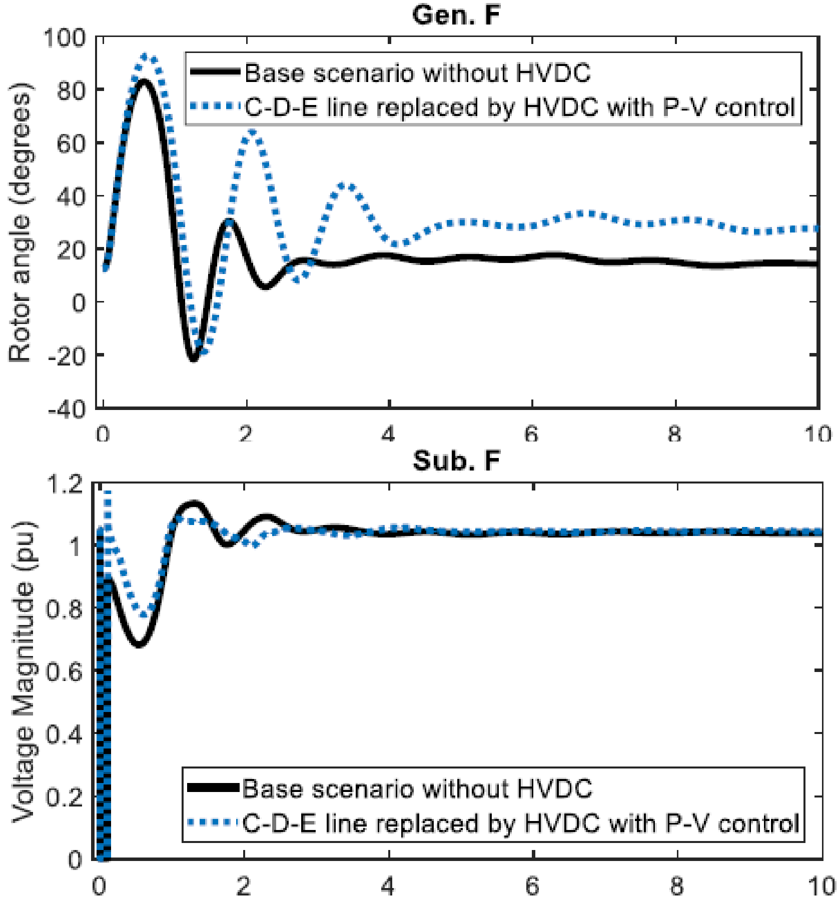




- CCT = 133 ms for base case
- CCT = 133 ms for **P-PF control** with PF=0.95
- CCT = 177 ms for **P-V control**

HVDC option 1:





- CCT = 103 ms for base case
- Case unstable for **P-PF control** with PF=0.95
- CCT = 103 ms for **P-V control**

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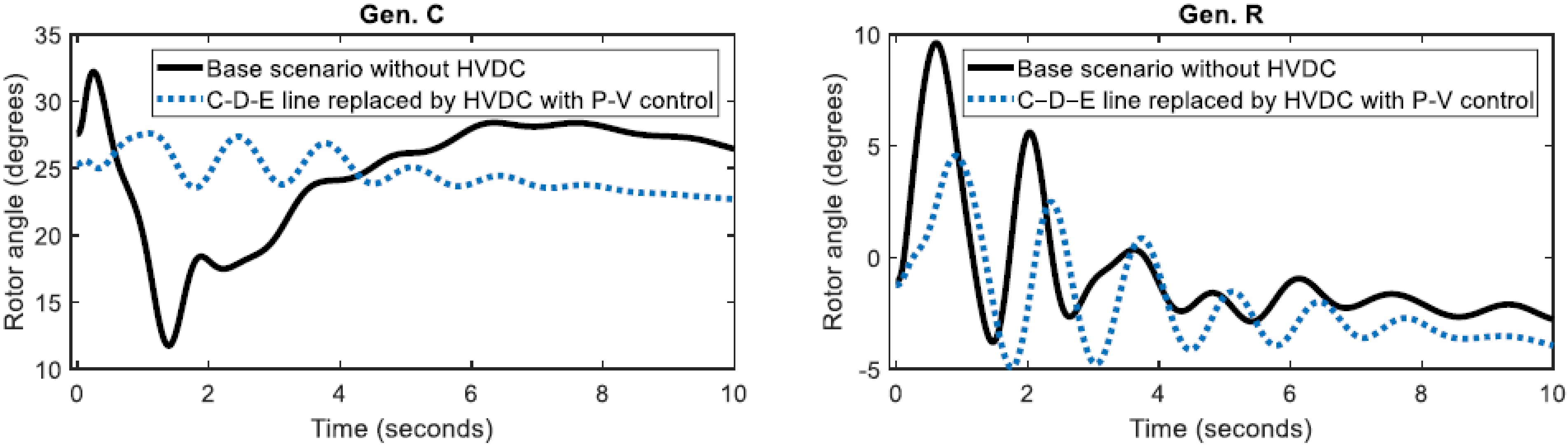
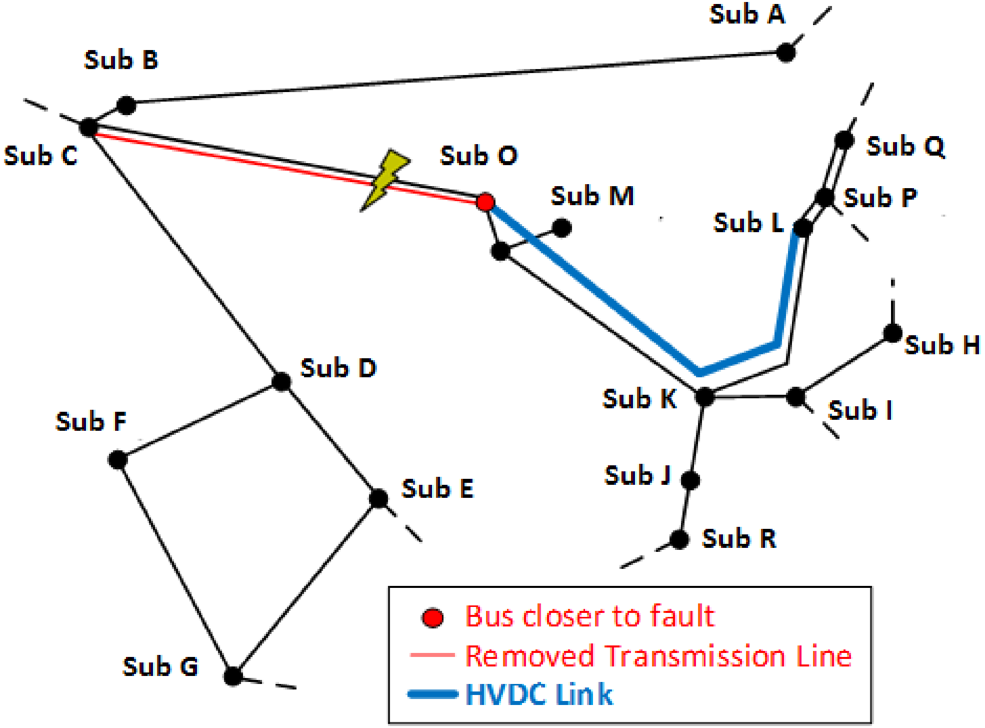
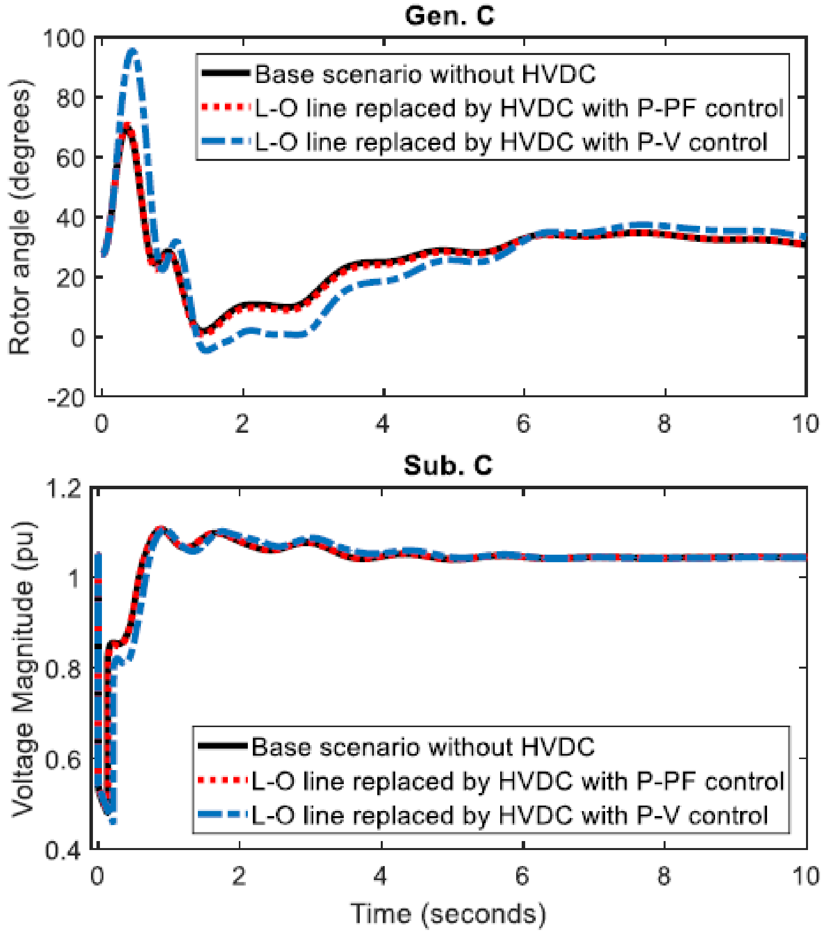

Gen. C
Base scenario without HVDC
C-D-E line replaced by HVDC with P-V control
Rotor angle (degrees)
35
30
25
20
15
10
0
2
4
6
8
10
Time (seconds)
Gen. R
Base scenario without HVDC
C−D−E line replaced by HVDC with P-V control
Rotor angle (degrees)
10
5
0
-5
0
2
4
6
8
10
Time (seconds)

HVDC option 3:





- CCT = 133 ms for base case
- CCT = 133 ms for **P-PF control** with PF=0.95
- CCT = 214 ms for **P-V control**

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Takeaways

- VSC-HVDC will change system dynamics/characteristics
- HVDC with PV control improves synchronization
- HVDC with P-pf control can have negative impacts based on network location
- HVDC decouples parts of network
- Lines in well meshed areas are better candidates, dilutes negative impacts

Ongoing Effort

- Identify and understand **changes in reactive power sharing**.
- Carry out **small-signal stability analysis** to identify possible control interactions and improve control settings.
- Use more **detailed VSC-HVDC model** with advanced control schemes.

Thank you. Questions?

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