CHANGING WHAT'S POSSIBLE

Analysis of CD-PAR Benefits and Technical Performance

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ELECTRIC POWER RESEARCH INSTITUTE

Compact Dynamic Phase Angle Regulators (CD-PAR) for Transmission Power Routing

Advanced Research Projects Agency • ENERGY

Varentec
advanced energy solutions

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SOUTHERN COMPANY

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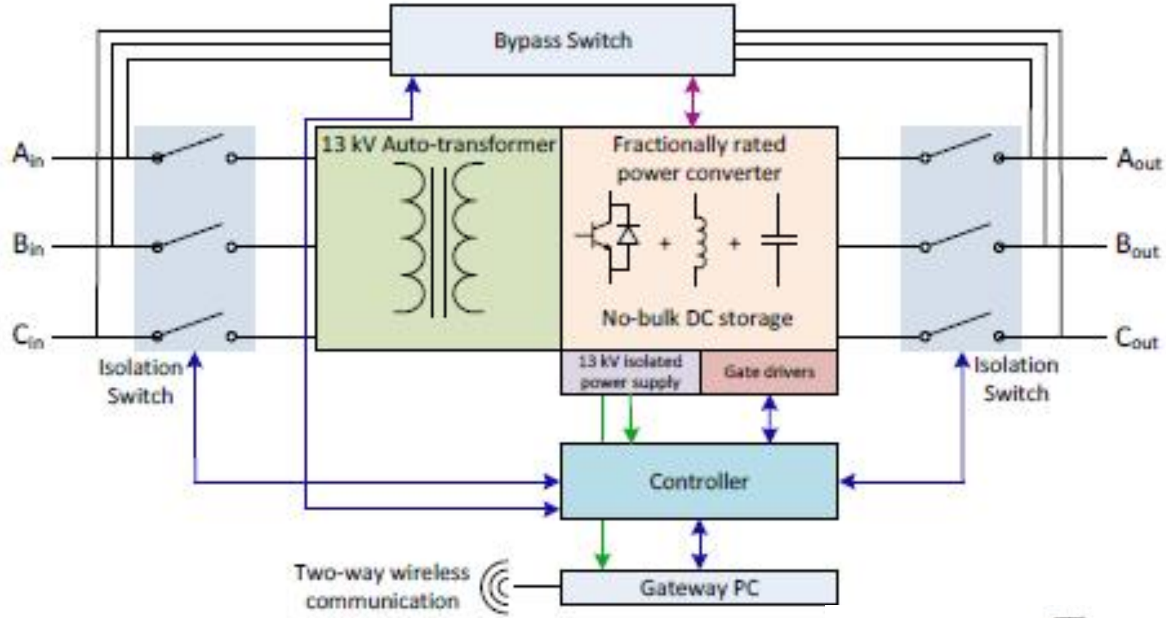
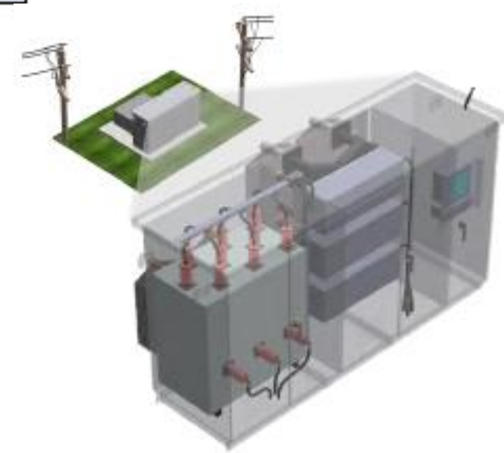
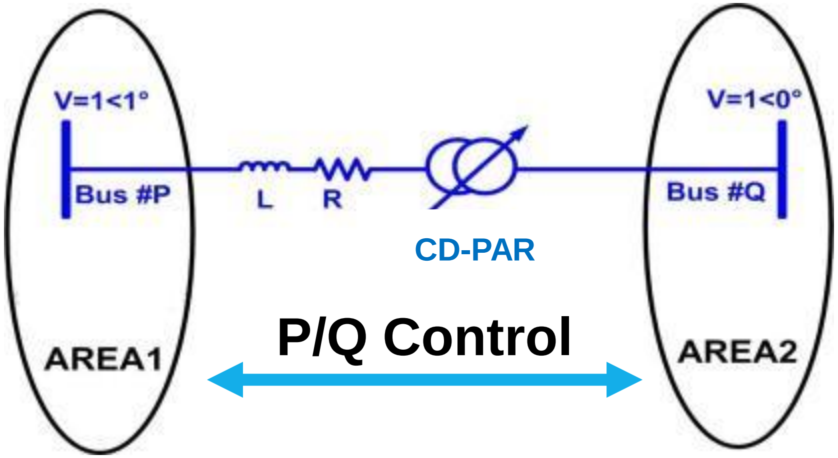
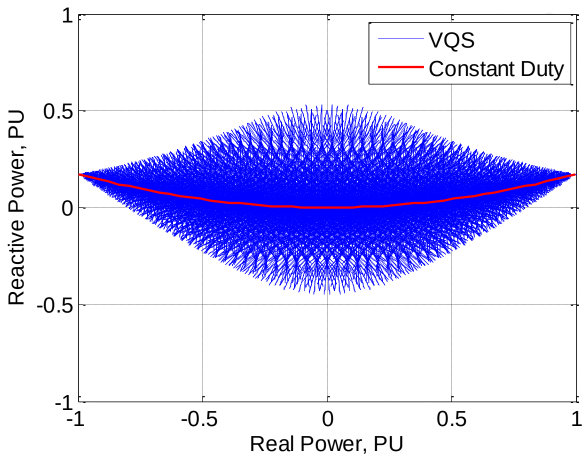




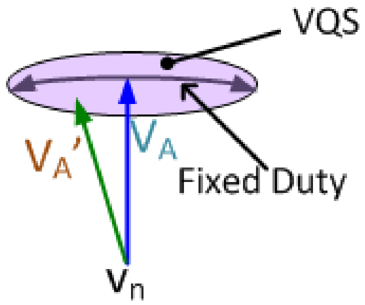
CD-PAR Objective

Control of P/Q Between Two Buses





- Control phase angle to control real power
- Control voltage magnitude to control reactive power
- Control real and reactive power dynamically
- Can be installed around existing sectionalizers



VQS enables in-phase injection

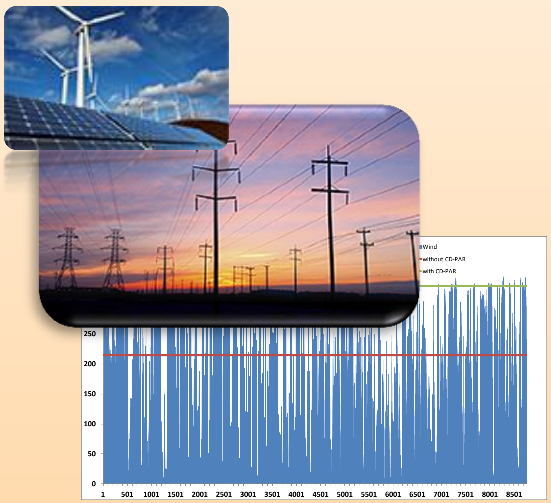
Goals of the study

- **Contribute to articulate value proposition of CD-PAR technology:**
  - Evaluate the impact of CD-PARs on system metrics including thermal overload relief, stability, and reliability improvement
  - Evaluate the use of CD-PARs to increase transmission capacity:
    - Divert power flow to reduce congestion
    - Improve voltage and angle stability
    - Control strategies: preventive measure - remedial measure
  - Analysis of the use of CD-PARs to improve distribution system efficiency and utilization

Approach

- Case studies on synthetic and actual power system models

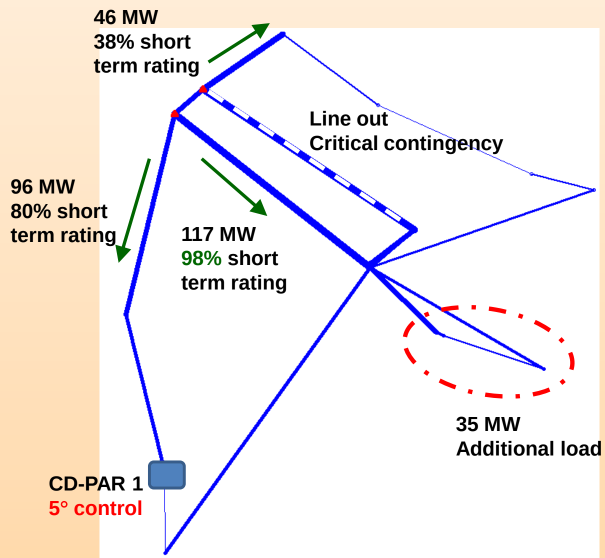
Transmission



•Reduced wind generation curtailment

•Two systems: Alberta Electric System, Utility in NY

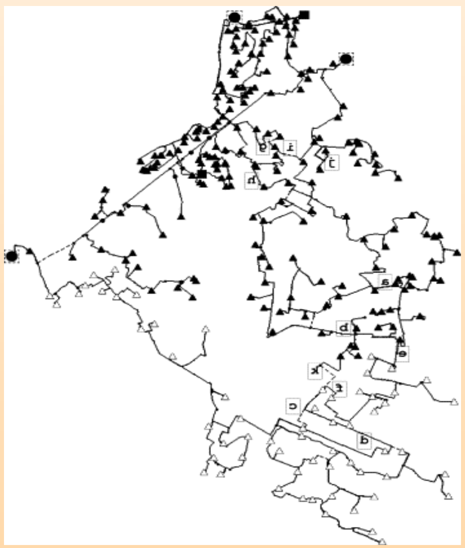
Sub-transmission



• Increased network loadability

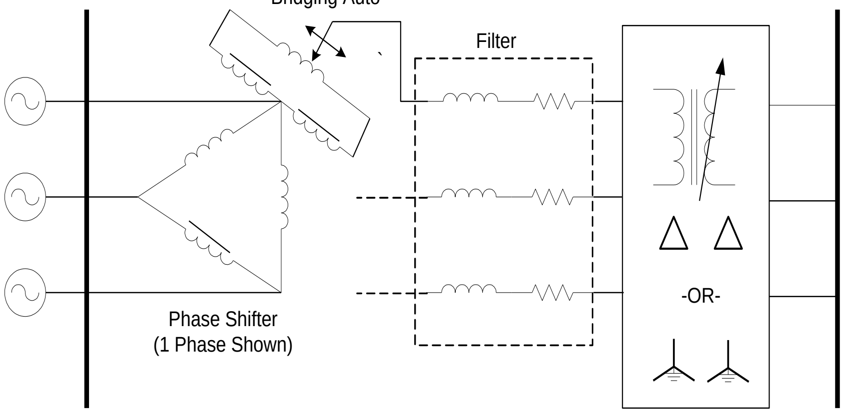
• Differ investment

Distribution

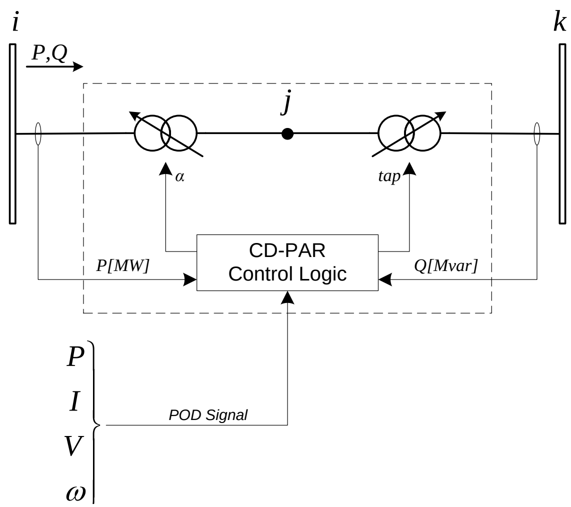


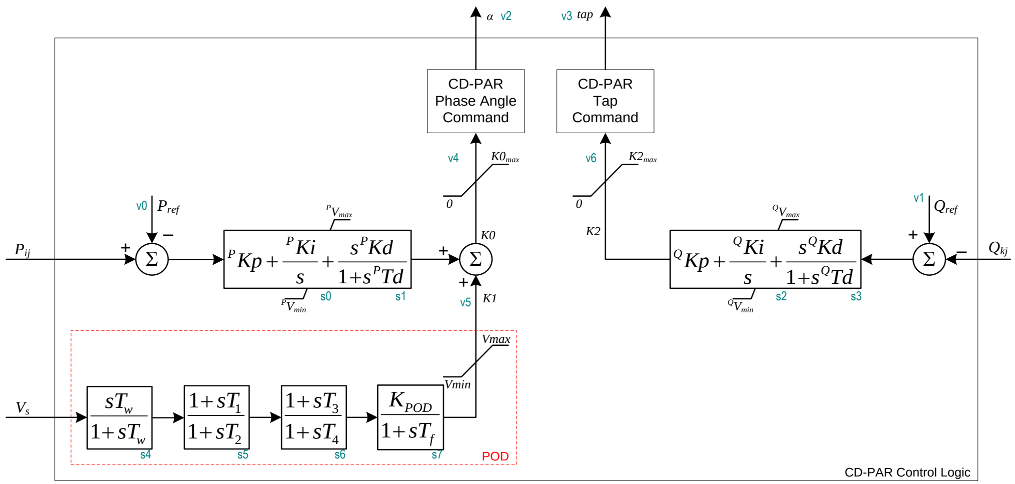
• Improved utilization by balancing load among feeders and substations

Modeling for system studies



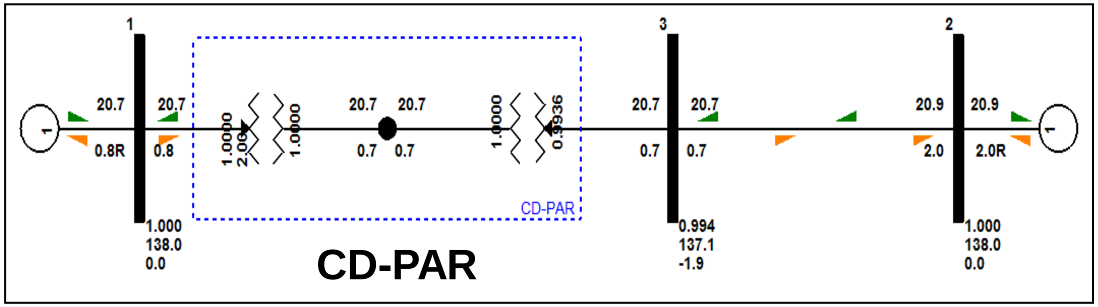
For OpenDSS: 3-phase model



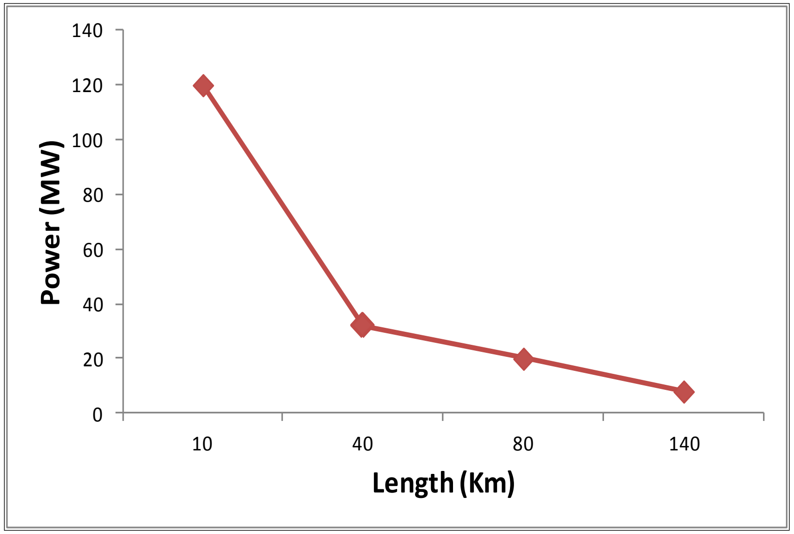


For PSS/E: Static and dynamic models

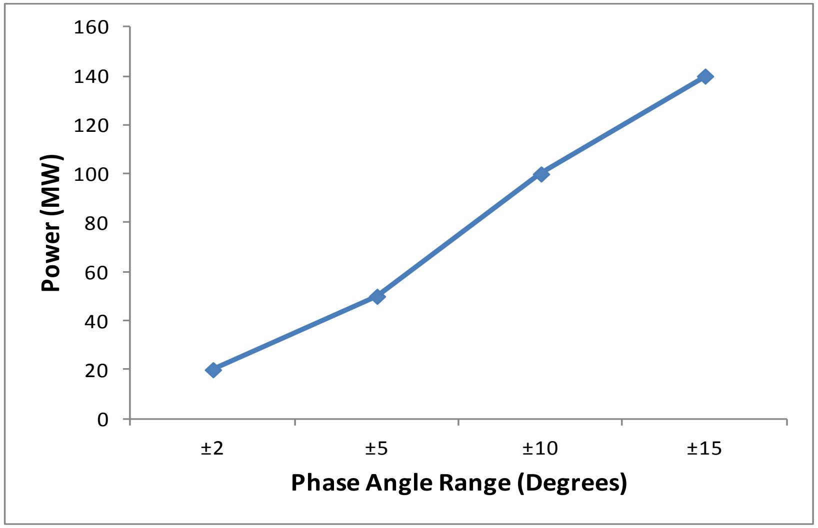
CD-PAR Control Capability



- Nominal voltage: 138.0 k V
- CDPAR sec. voltage: 500 V
- 90 km transmission line
- Maximum Phase Angle of CD-PAR α : ±2 degrees

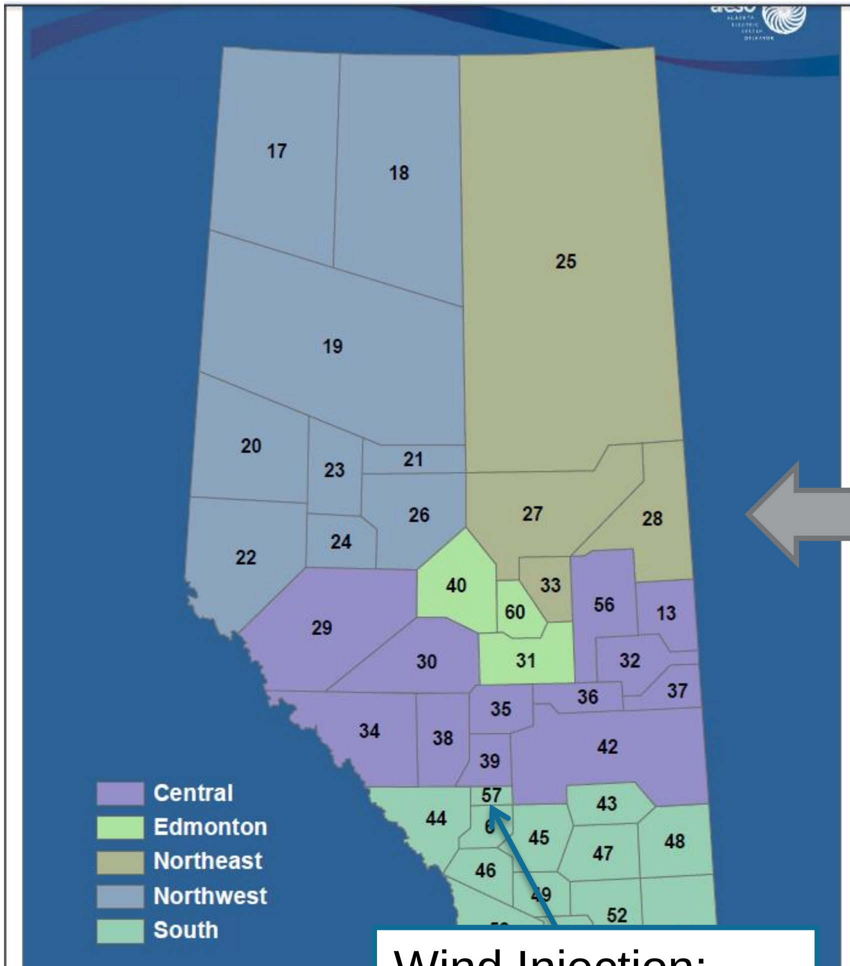


Active power vs. line length



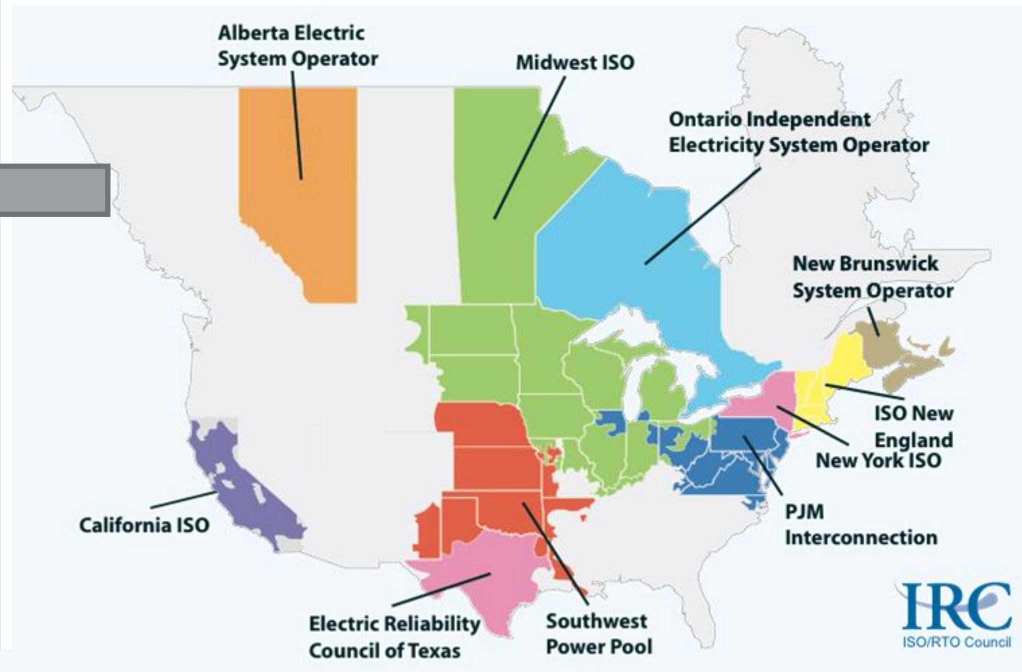
Active power vs. max. CD-PAR phase angle shift

Use of CD-PAR to Improve Wind Integration

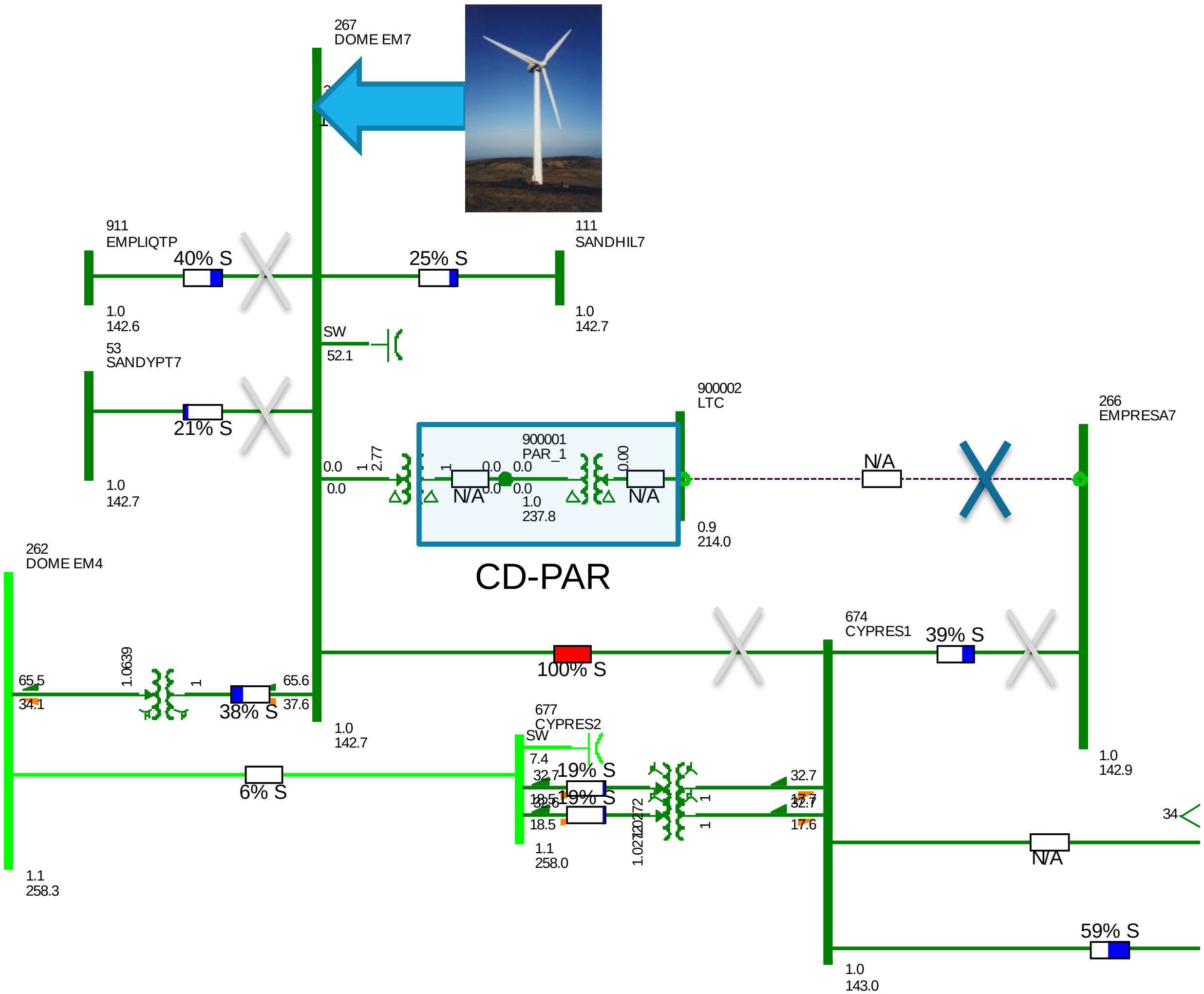


Wind Injection: Calgary

- **Alberta Electric System Operator Coverage Map**
- **Hypothetic case**

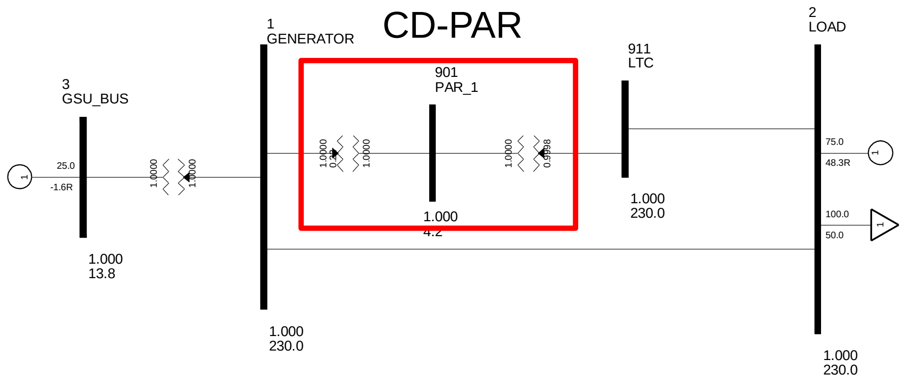


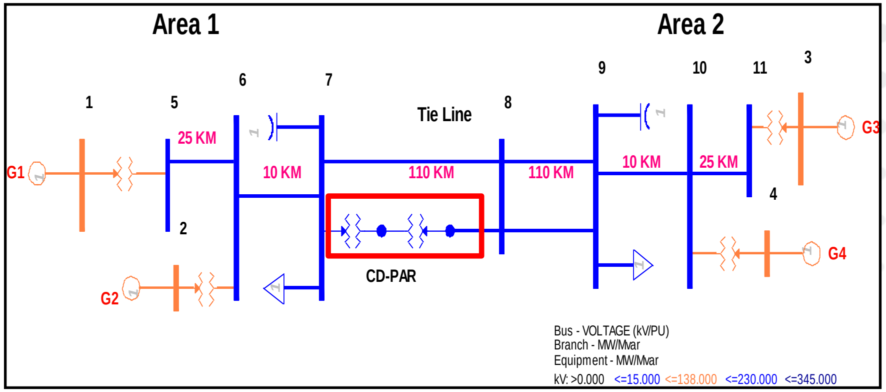
Scenario: Interconnection request for 350 MW Wind Plant

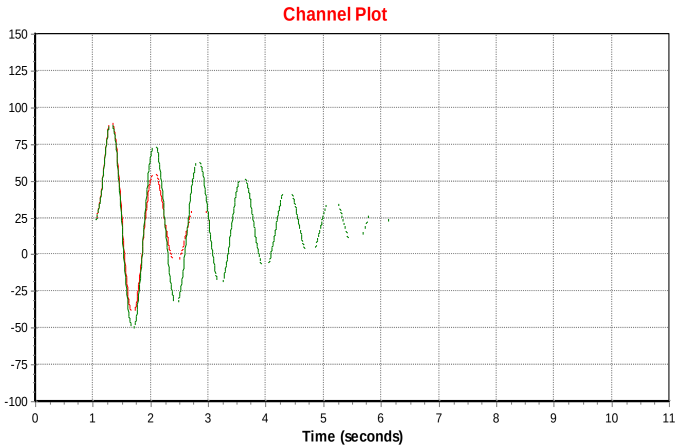


- Injection limit due to N-1 conditions
- Limit without CD-PAR: **215 MW**
- Limit with CD-PAR: **330 MW**
- Wind spillage reduction 174 GWh
- CD-PAR controlled for N-1 as well as N conditions:
  - ⇒ **Short term rating > permanent rating**

Use of CD-PAR for Power Oscillation Damping



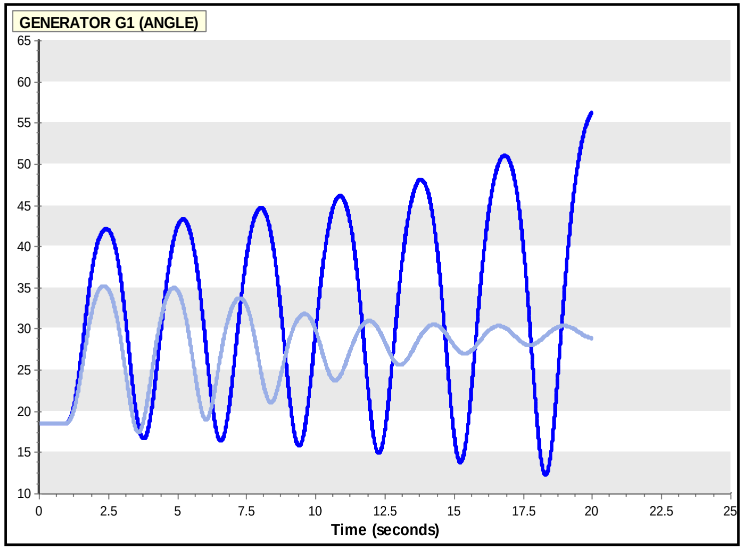




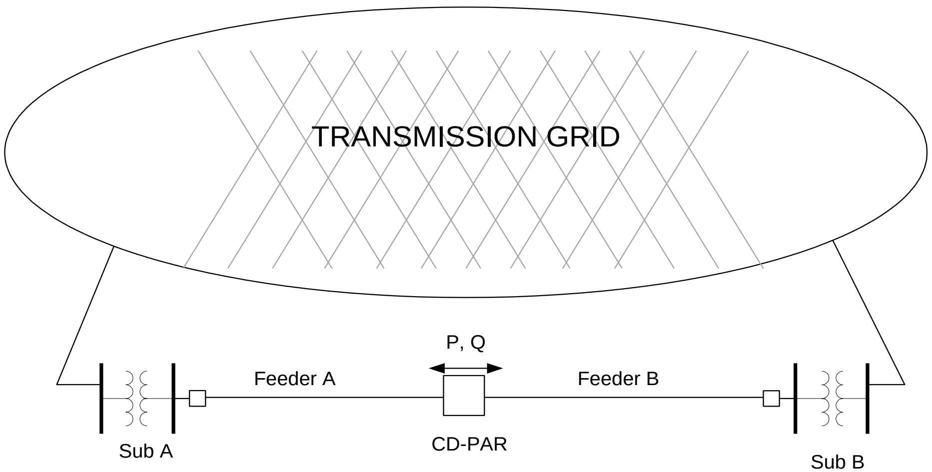
Generator angle excursion

No CD-PAR

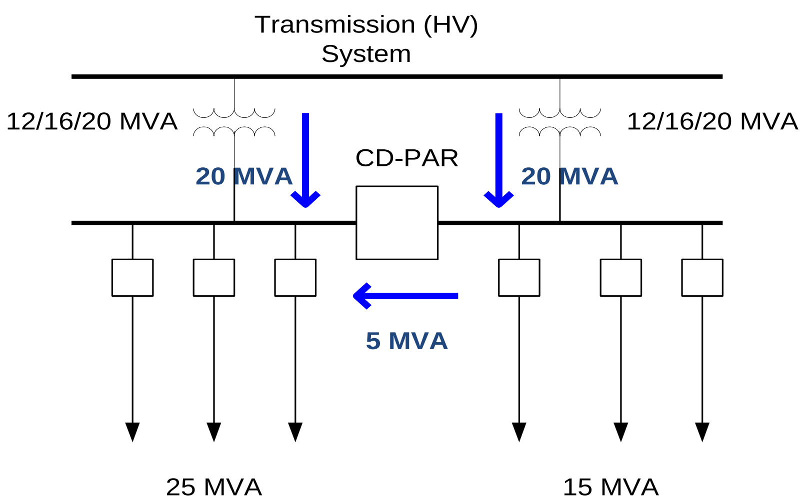
230/13.6 kV CD-PAR



Potential Applications in Distribution Systems



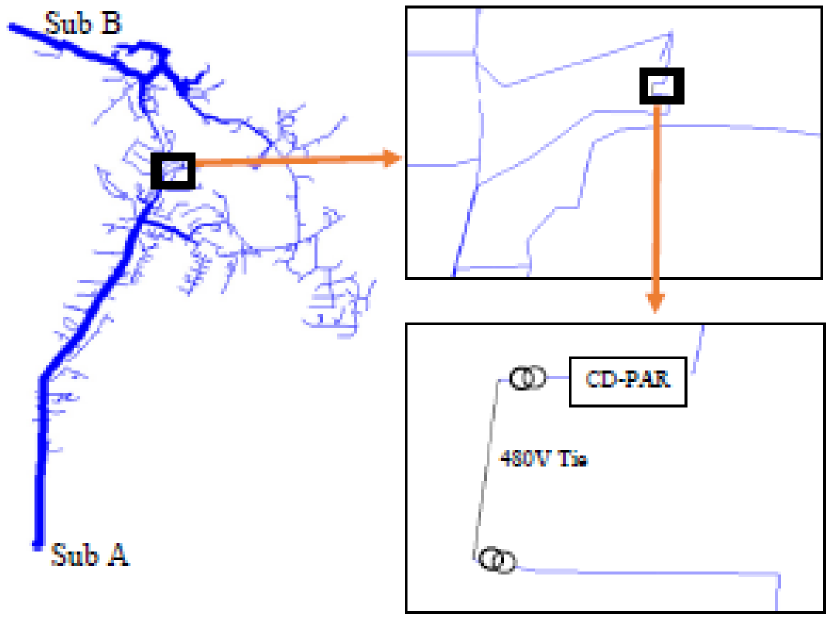
A) Feeder Support Between Remote Substations



B) Balancing Substation Transformer Loading

Feeder Support Between Remote Substations

OpenDSS Model of Actual Feeders



CD-PAR capabilities are affected by:

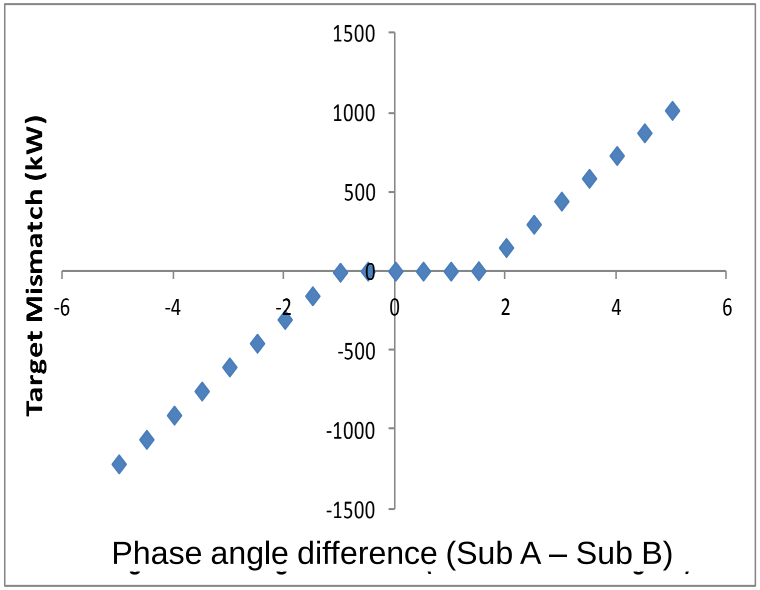
- Feeder characteristics where CD-PAR will be installed
- Feeder loading
- Variation of phase angle difference on transmission system

Objective of the Study

- Analyze the capability of the CD-PAR to attain desired power flows to the load at the feeders' ends

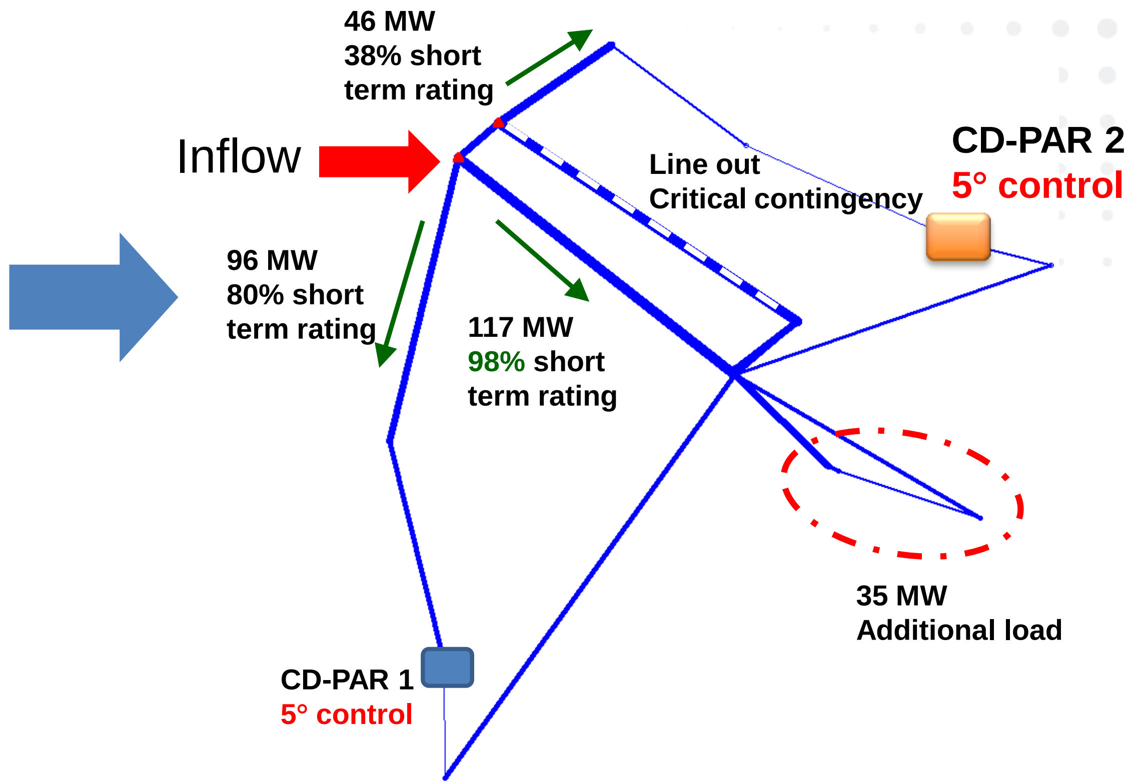
Control Target

- Each feeder serves half the load (equal sharing)



Sub-transmission system case

Combined distribution and 60 kV subtransmission network that feed a medium size city in CA



- Maximum additional load with CD-PAR 1: 35 MW
- Maximum additional load with both CD-PAR 2: 55 MW

Conclusions

- CD-PAR can improve efficiency and utilization of transmission and distribution systems
- CD-PAR can be effectively used to damp power system oscillations
- The use of CD-PAR for multiple uses may improve the value proposition – technically feasible
- Control interactions need to be considered:
  - Between the different control loops of a CD-PAR device
  - With other devices on the system
- Practical implementation: Event based Special Protection Scheme

What else is needed to demonstrate the value proposition?

- Detailed evaluation of other potential benefits:
  - i.e.: enabler of system flexibility
- Economic assessment of benefits and cost:
  - benefits, and beneficiaries
- Detailed technical and economic comparison with alternative solutions
- Mathematical models to determine optimal location and capacity of CD-PARs
- Demonstrate the role of power flow controllers in the grid of the future – The integrated grid