



CHANGING WHAT'S POSSIBLE

# **Varentec: Compact Dynamic Phase Angle Regulator (CD-PAR) Power System Economics**

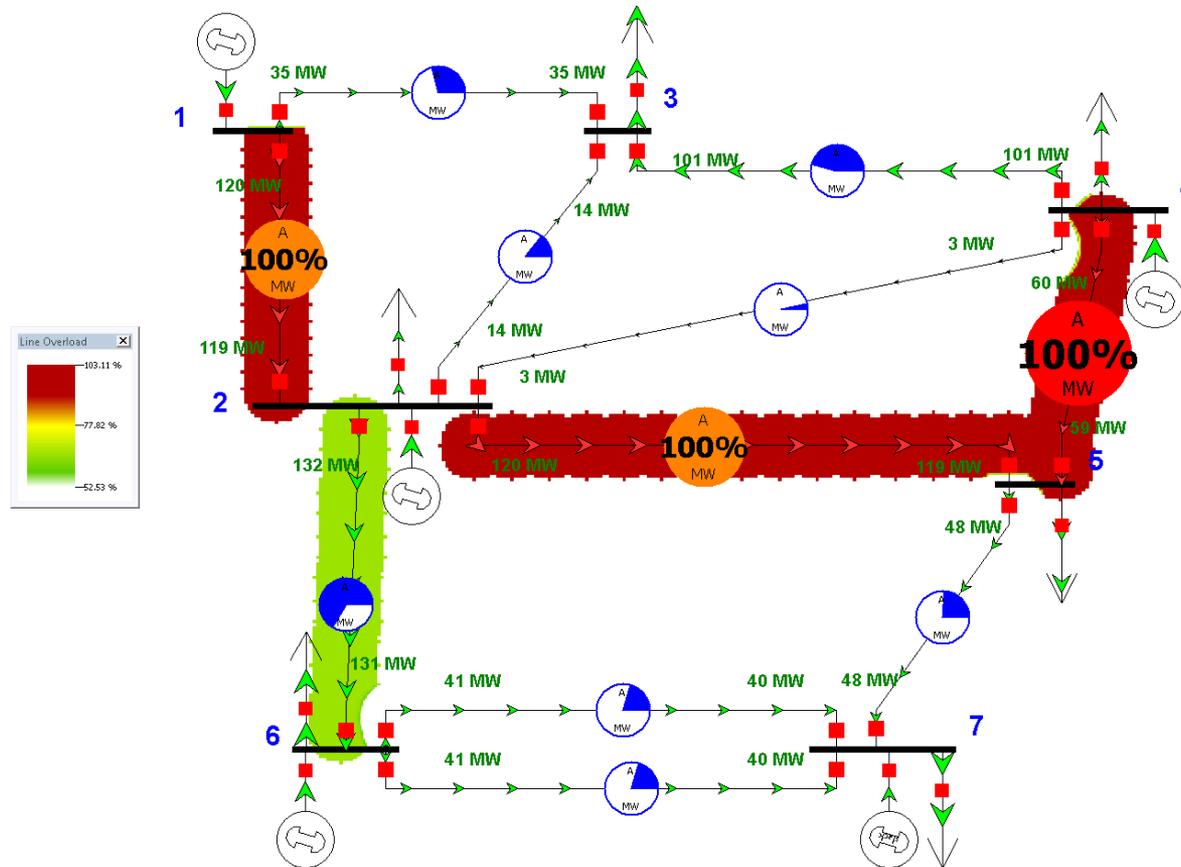
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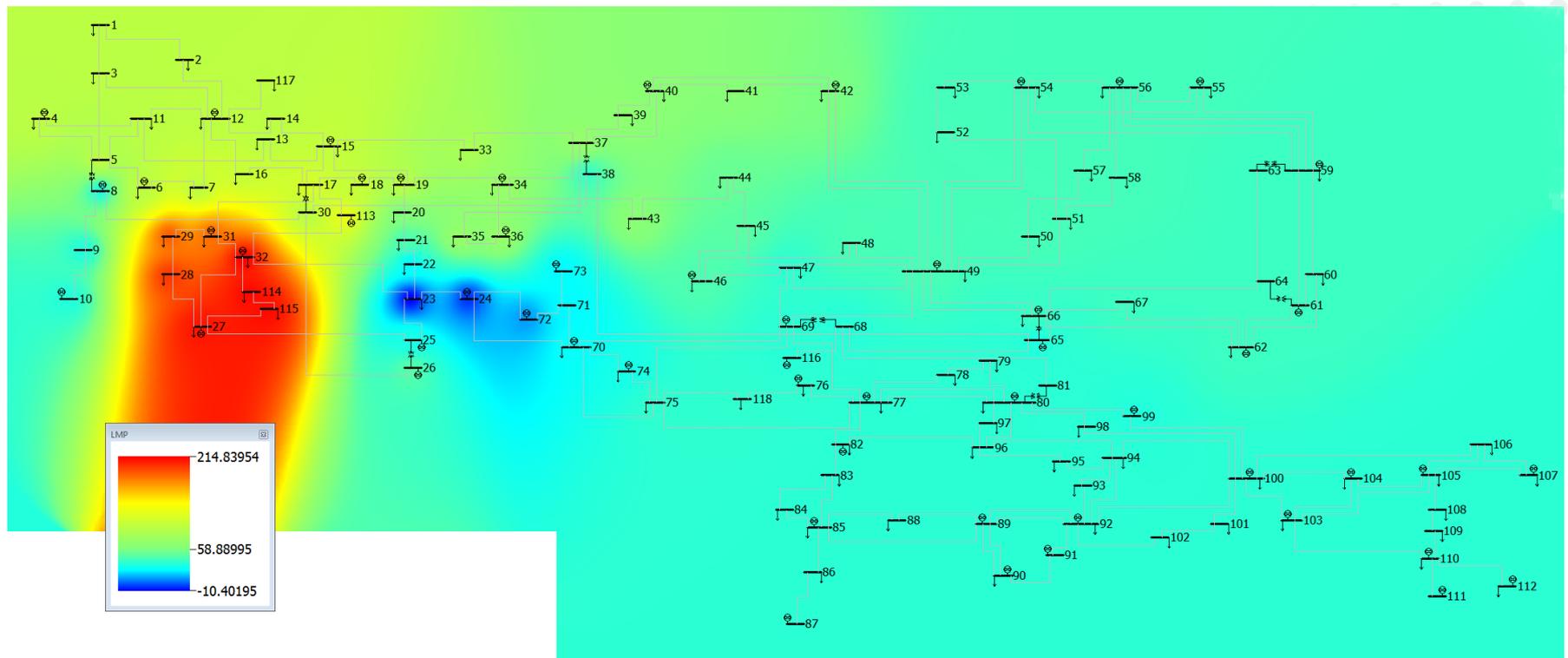
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# Limited Controllability of Power Flows

- Power flows in the grid are difficult to control: once the injections and extractions are defined, power will flow where it has to.

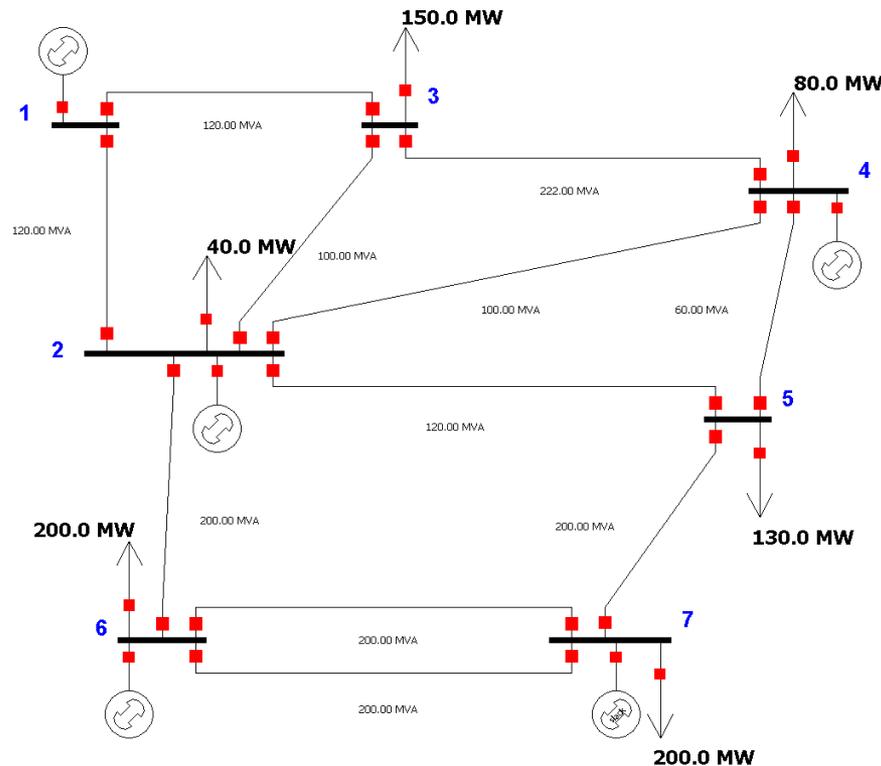


# Need for Flexible Power Flow Control



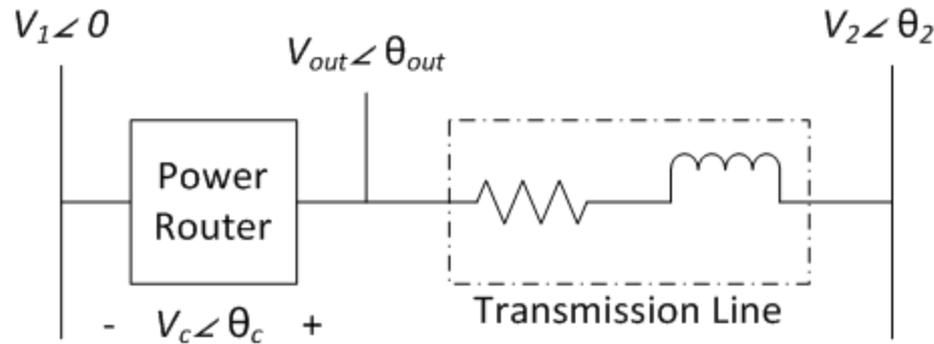
- For a variety of reasons the location and size of injections and extractions of power are changing. This will affect congestion.
- Power routers enable active flow control making the grid more flexible.

# Integration into Generator Dispatch

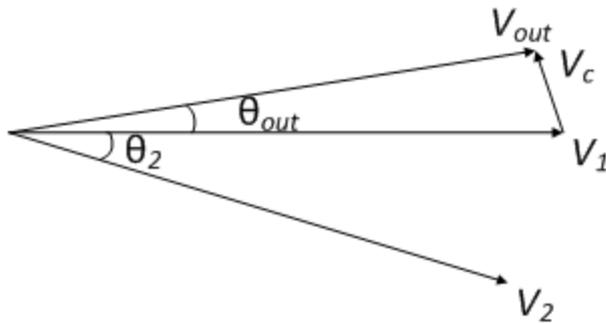


- PRs can further optimize dispatch, improving system economics: prices, fairness, and asset utilization.
- The team derived new equations and modified algorithms to take into consideration the effect of routing and their controls.

# Algorithm Development: PR Control Model

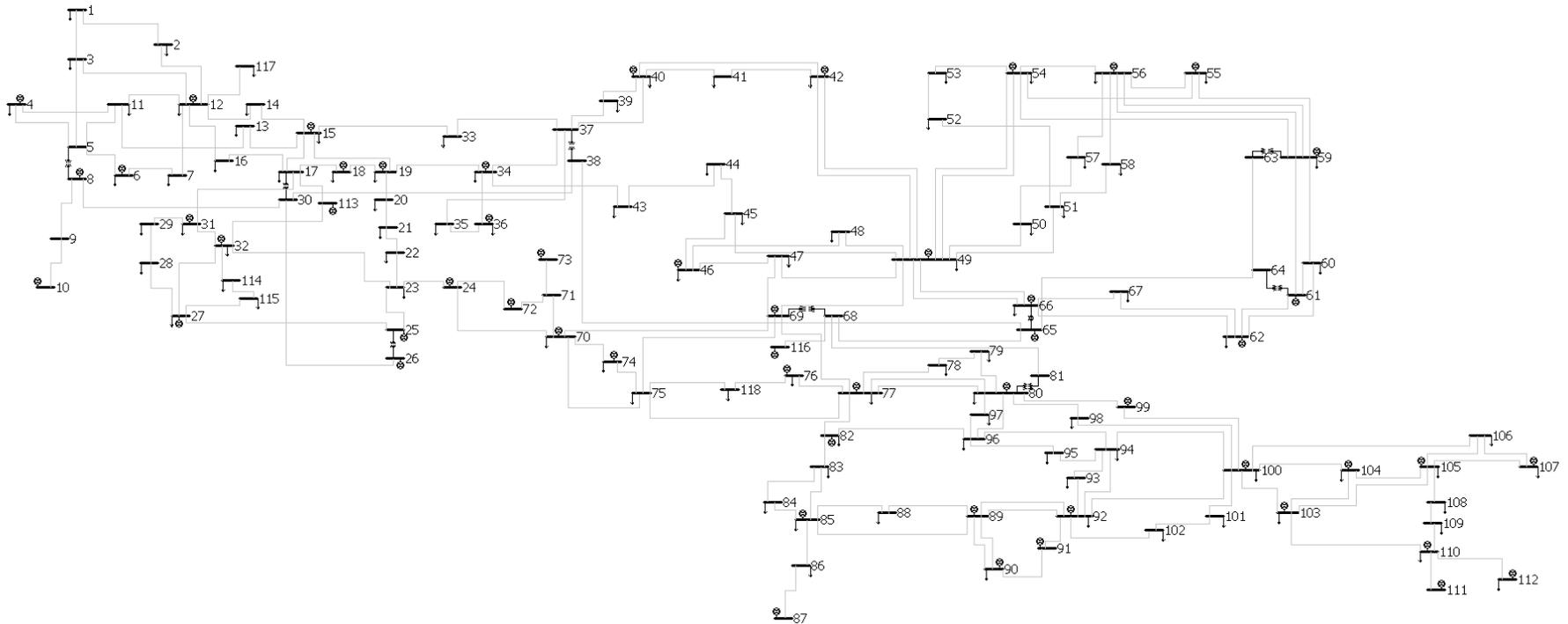


$$P_{12} = V_1 g_{12} - V_1 V_2 \left[ g_{12} \cos(0 - \theta_2 - \theta_c) + b_{km} \sin(0 - \theta_2 - \theta_c) \right]$$



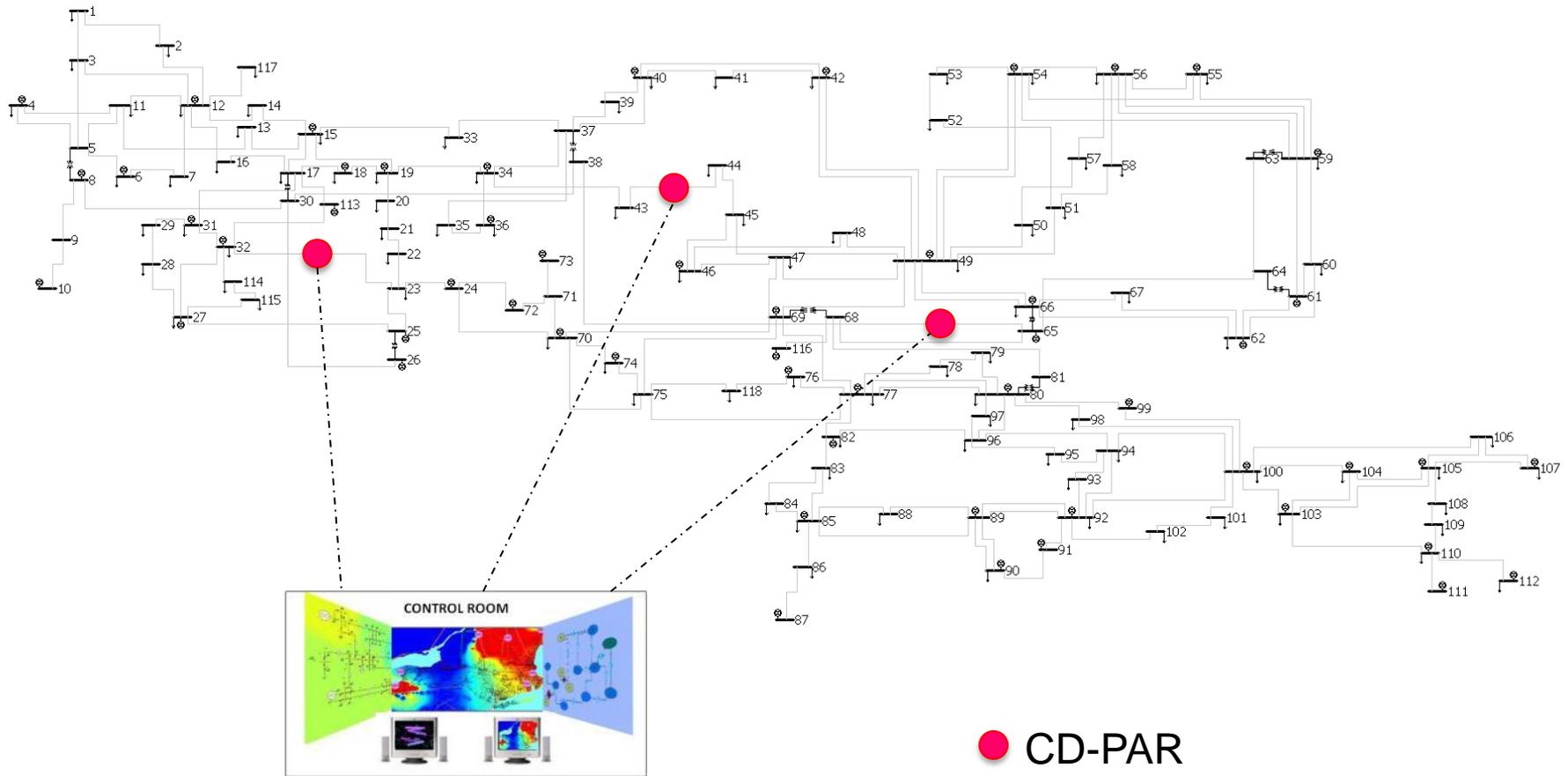
- PR control uses the voltage phase angle injection
- This makes the impact of PRs on real power flows direct.

# Algorithm Development: Case Used



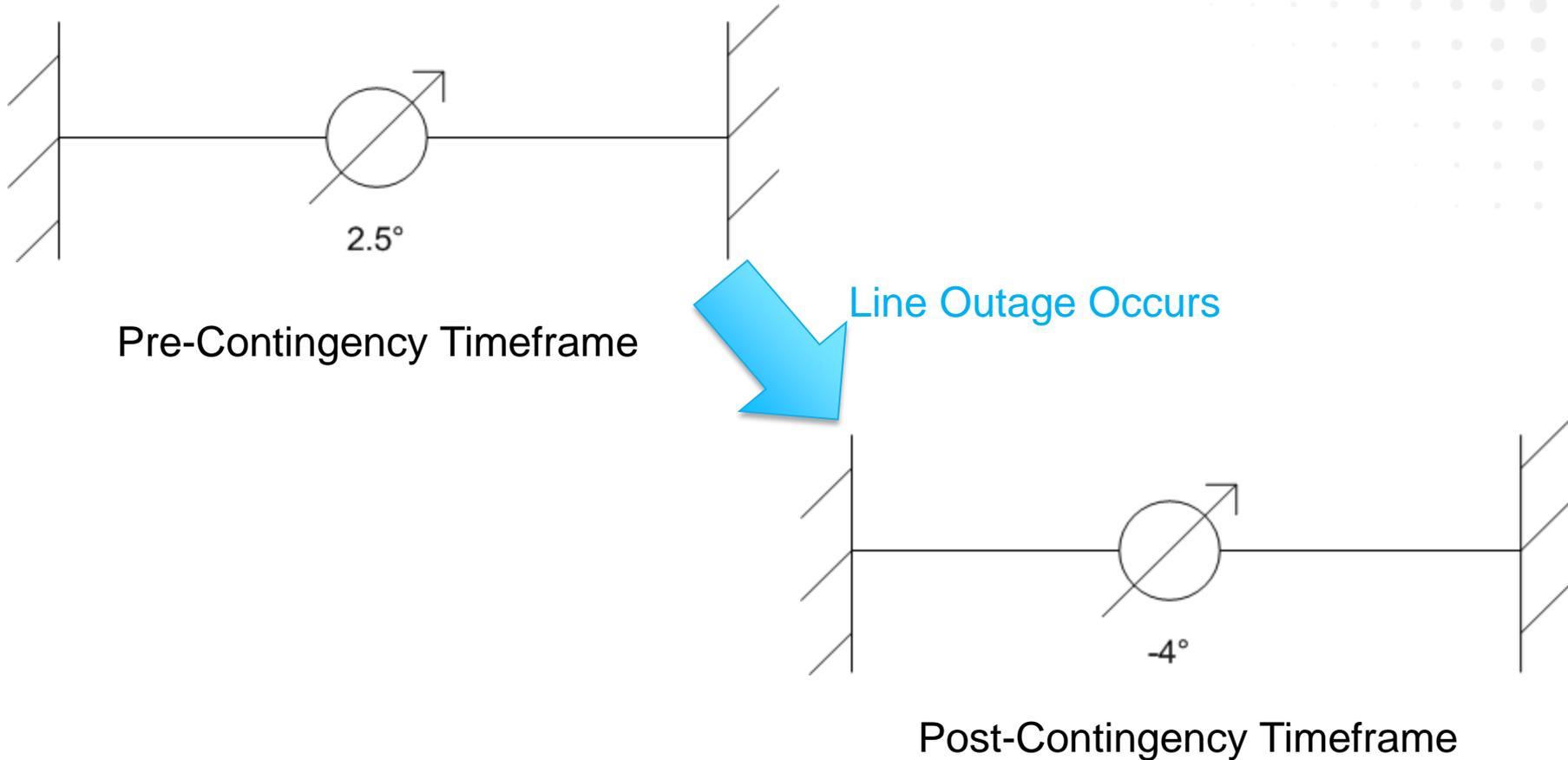
System Peak Loading: 6 GW  
54 Generators, 91 Loads  
1 year simulation

# Algorithm Development: Centralized Control



- PRs could be dispatched from the control room in response to alleviating congestion during contingency situations

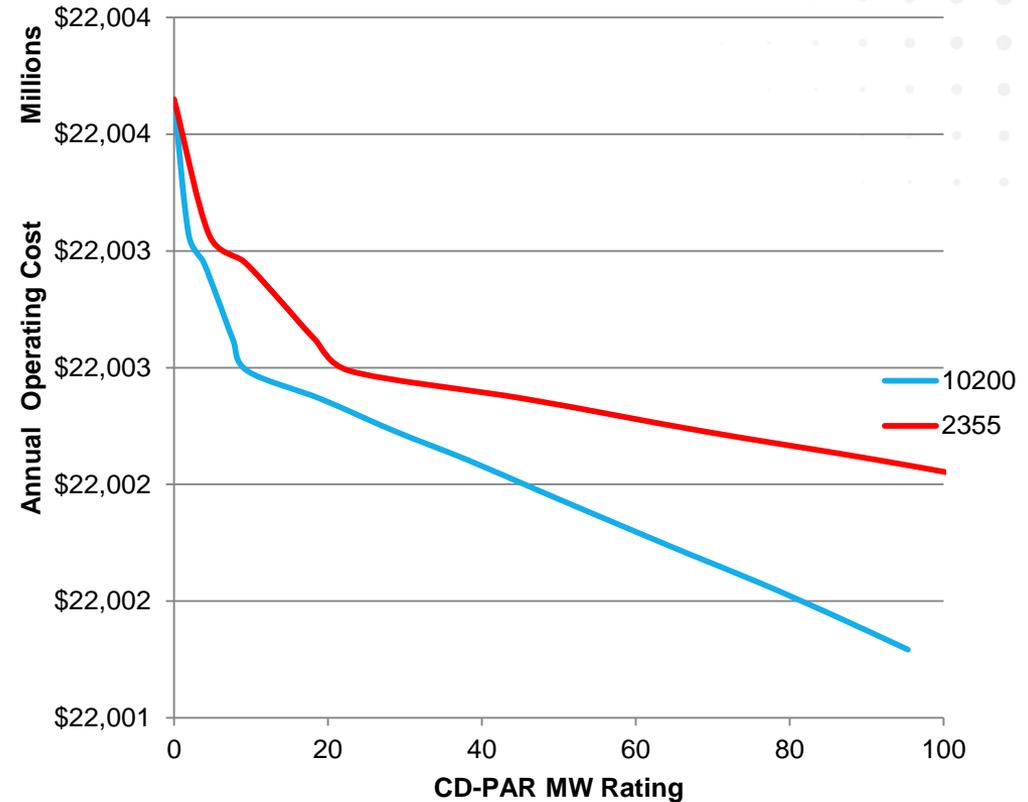
# Algorithm Development: Corrective Control



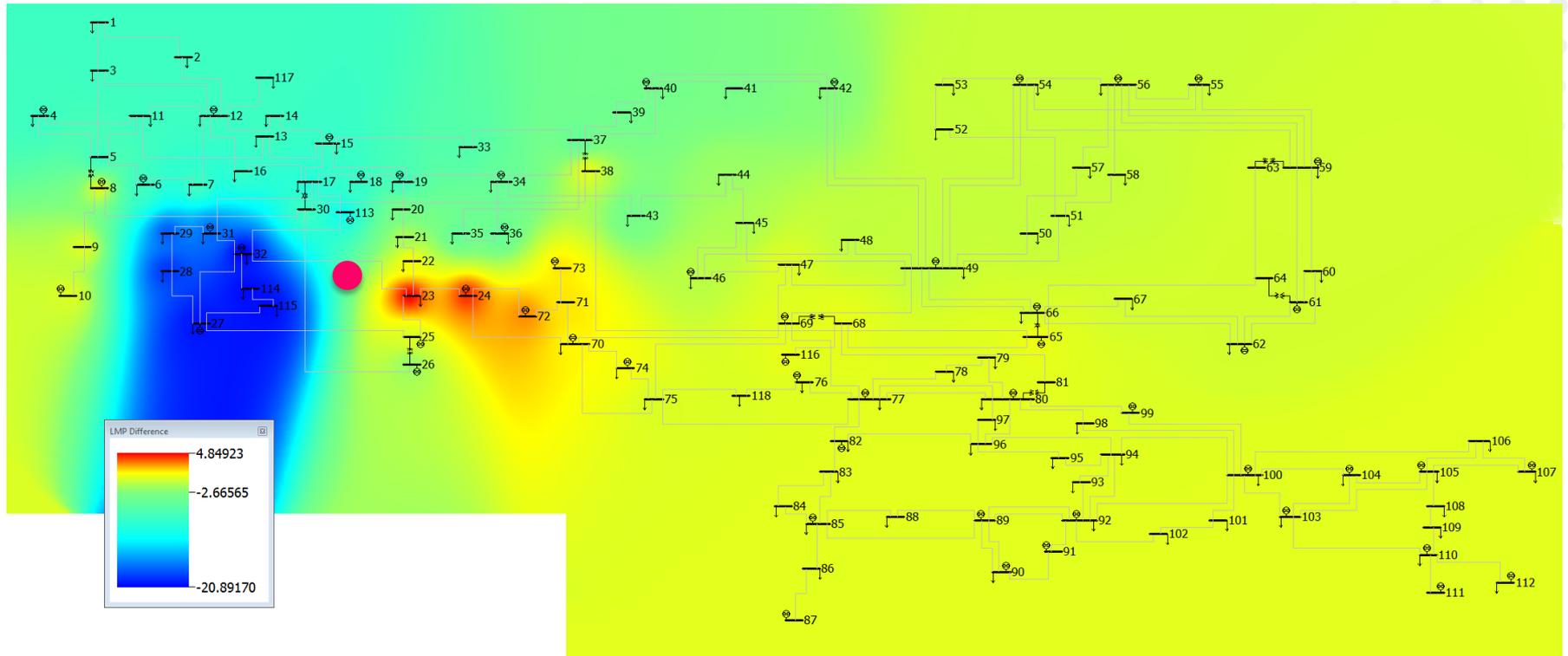
- PR has ability to quickly change setpoints in reaction to a contingency

# ISO Results: Impact on Operating Cost

- Yearly simulation.
- ISO-scale system
- OPF algorithm used.
- Flexible (FSCOPF) has similar trend.
- Different locations have different rates of savings.
- Operating cost will decrease to an asymptote as size of CD-PAR increases
- Savings per MW Rating invested are higher for the CD-PAR at lower ratings



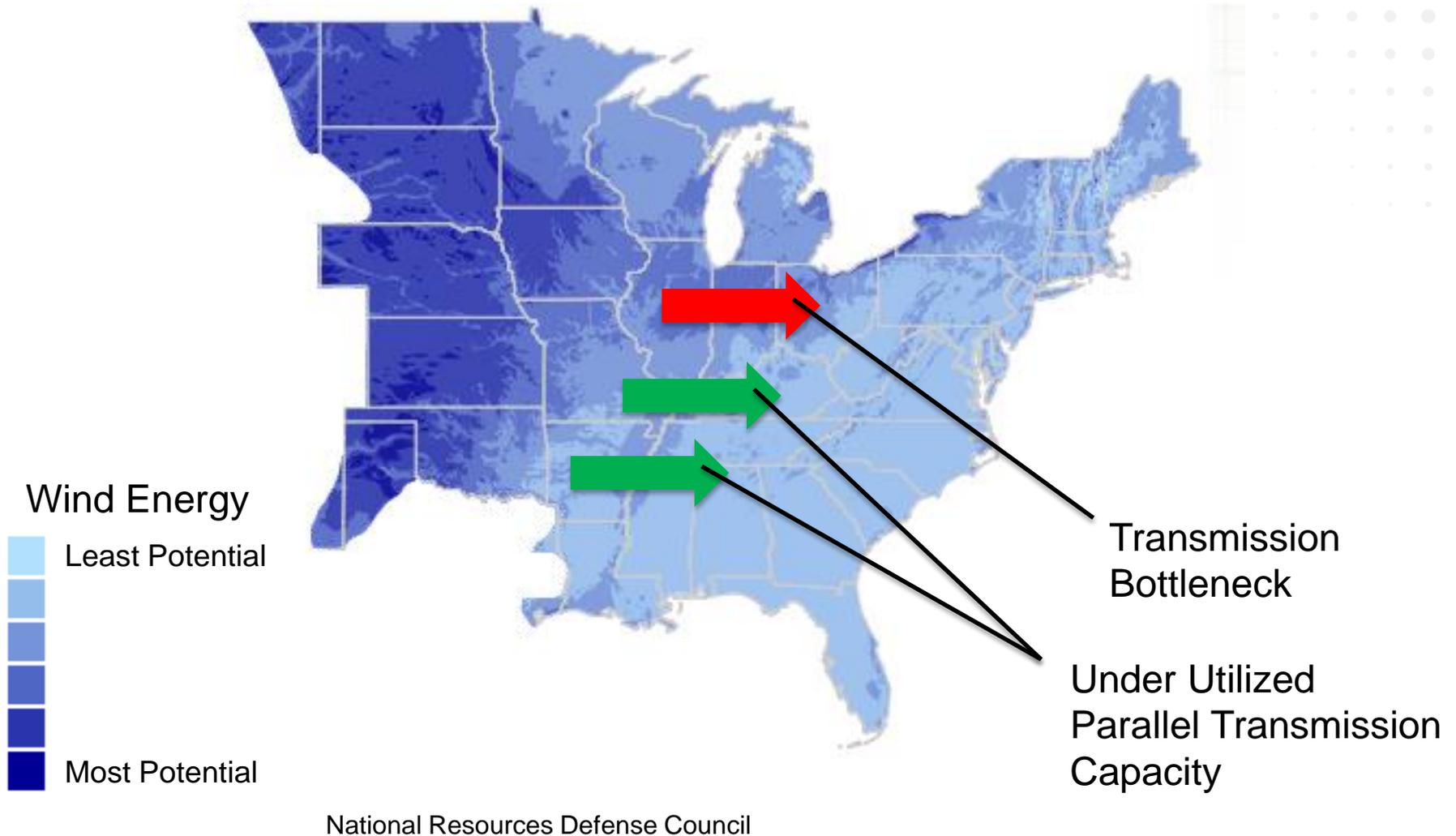
# Simulation Results: Impact on LMPs



● CD-PAR

- Gradient shows change in LMPs for a specific hour when compared to base case (no PR present)
- PR is acting to make LMPs converge throughout the system

# Future Applications



# Future Steps

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- ▶ **Complete Simulations with Flexible SCOPF.**
  - Additions of power flow control modeling to commercial dispatch software is needed to fully analyze all use cases and benefits of PRs.
- ▶ Study market design changes that would support investment in power routers.
- ▶ Study power routers in specific utilities and ISOs use cases to further demonstrate benefits.