ARPA-E 0670-4106

Non-wire Methods for Transmission Congestion Management through Predictive Simulation and Optimization

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Project Objectives

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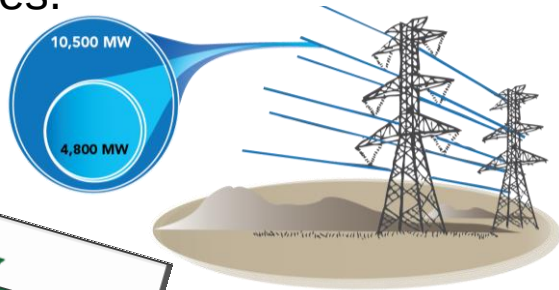
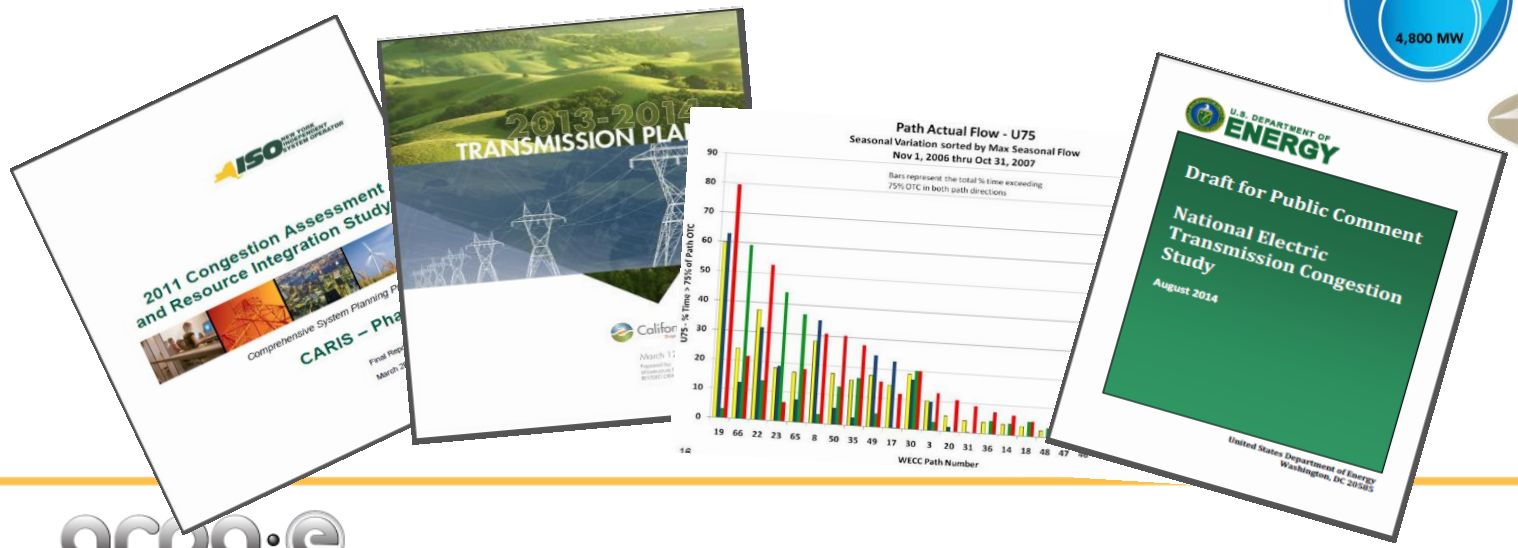
- Objective: ***"tap into unused capacities"*** to manage transmission congestion
- Motivation:
  - Significant congestion cost: NYISO $1.1B/2010; PJM $1.4B/2012
  - Transmission expansion facing challenges
  - Transmission congestion impacts grid development
- Our approach: Develop **real-time path rating (ATC – available transfer capability)** using advanced-computing-based methods, leading to the optimal use of transmission assets and deferral of building new lines.
  - Reduce path rating study time to 10 minutes.





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Real-Time Path Rating (ATC)

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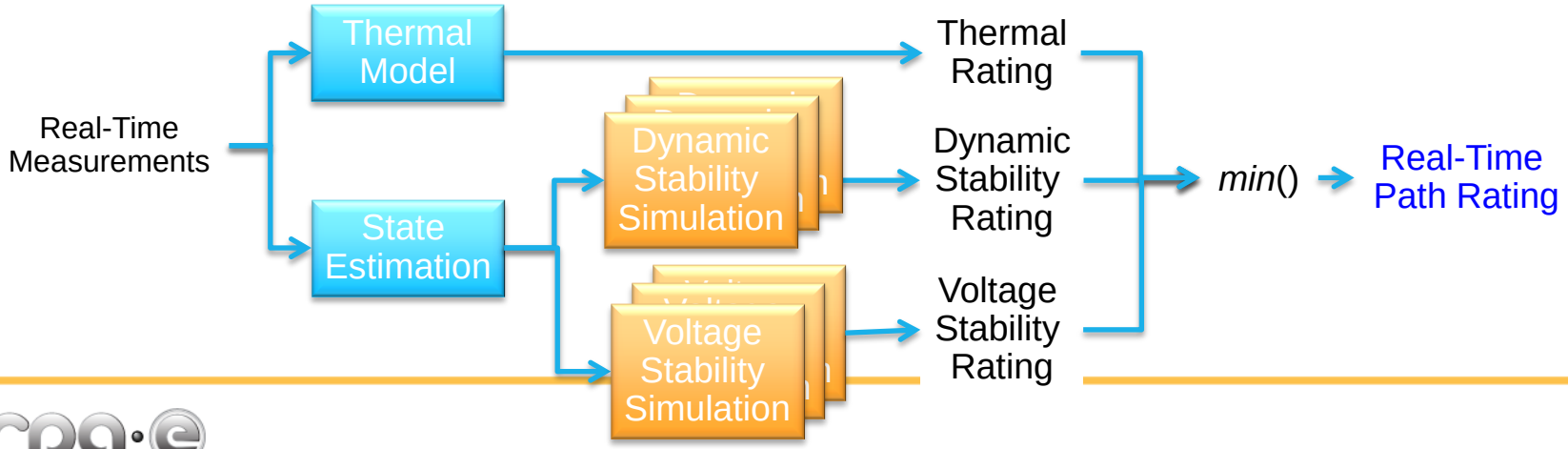
- Current Path Rating Practice and Limitations
  - Offline studies with worst-case scenario
  - Ratings are static for the operating season
  - ➔ The result: conservative (most of the time) path rating
- Real-Time Path Rating
  - On-line studies with current operating scenarios
  - Ratings are dynamic based on real-time operating conditions
  - ➔ The result: realistic path rating, leading to maximum use of transmission assets and relieving transmission congestion



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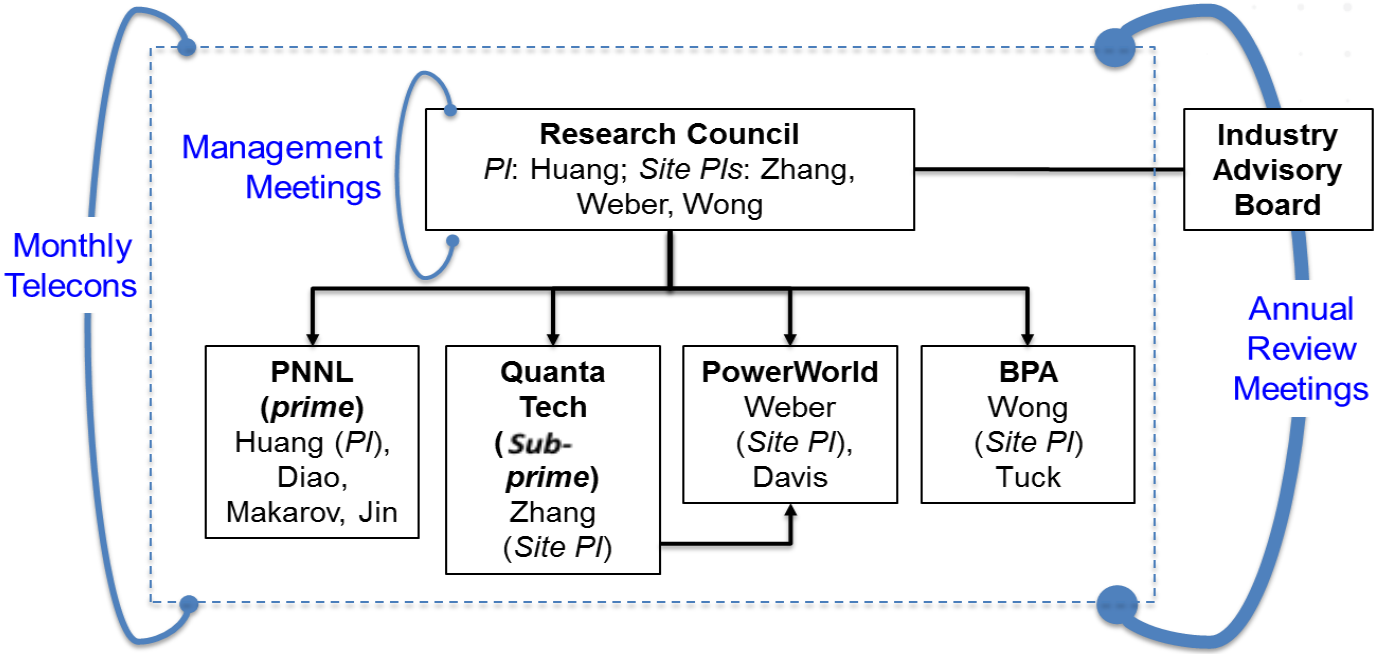
Project Team & Management



Industry Advisory Board:
José Conto - Principal Engineer, Electric Reliability Council of Texas
Anthony Johnson - Consulting Engineer, Southern California Edison
Xiaochuan Luo - Technical Manager, ISO-New England
Joshua Shultz - TVA
Dede Subakti - Director, Operations Engineering Services, CAISO

Project Tasks Update

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1. Project Planning

- 1.1.1 Initial project research plan
- 1.1.2 Software development plan
- 1.1.3 Update R&D plans

2. HPC based faster-than-real-time algorithms

- 2.1 Develop a test plan
- 2.2 Fast dynamic simulation
- 2.3 Fast voltage stability simulation

- 2.2.1 algorithms architectural design
- 2.2.2 decouple dynamic models
- 2.2.3 identify linear solvers
- 2.2.4 adaptive time stepping method
- 2.2.5&2.2.6 HPC code implementation

Define

Develop

Demonstrate

3. HPC based real-time path rating capability

- 3.1 Tool specifications, test plan, architectural design
- 3.2 Massive contingency analysis
- 3.3 Methods of simultaneous path rating for multiple paths
- 3.4 Benefit analysis
- 3.5 Program implementation

4. Integrate and demonstrate on a commercial software platform

- 4.1 Tool integration specifications
- 4.2 integrate full-topology model
- 4.3 adapt a subset of dynamic model library
- 4.4 Demonstrate tool

5. Technology transfer and outreach (TTO)

- 5.1 T2M plan
- 5.2 IP management plan
- 5.3 Industry advisory board
- 5.4 Use case analysis
- 5.6 Partner engagement
- 5.7 Transition/commercialization strategy

Completed
Ongoing
Delayed/Scope Change

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Flowchart Finalized

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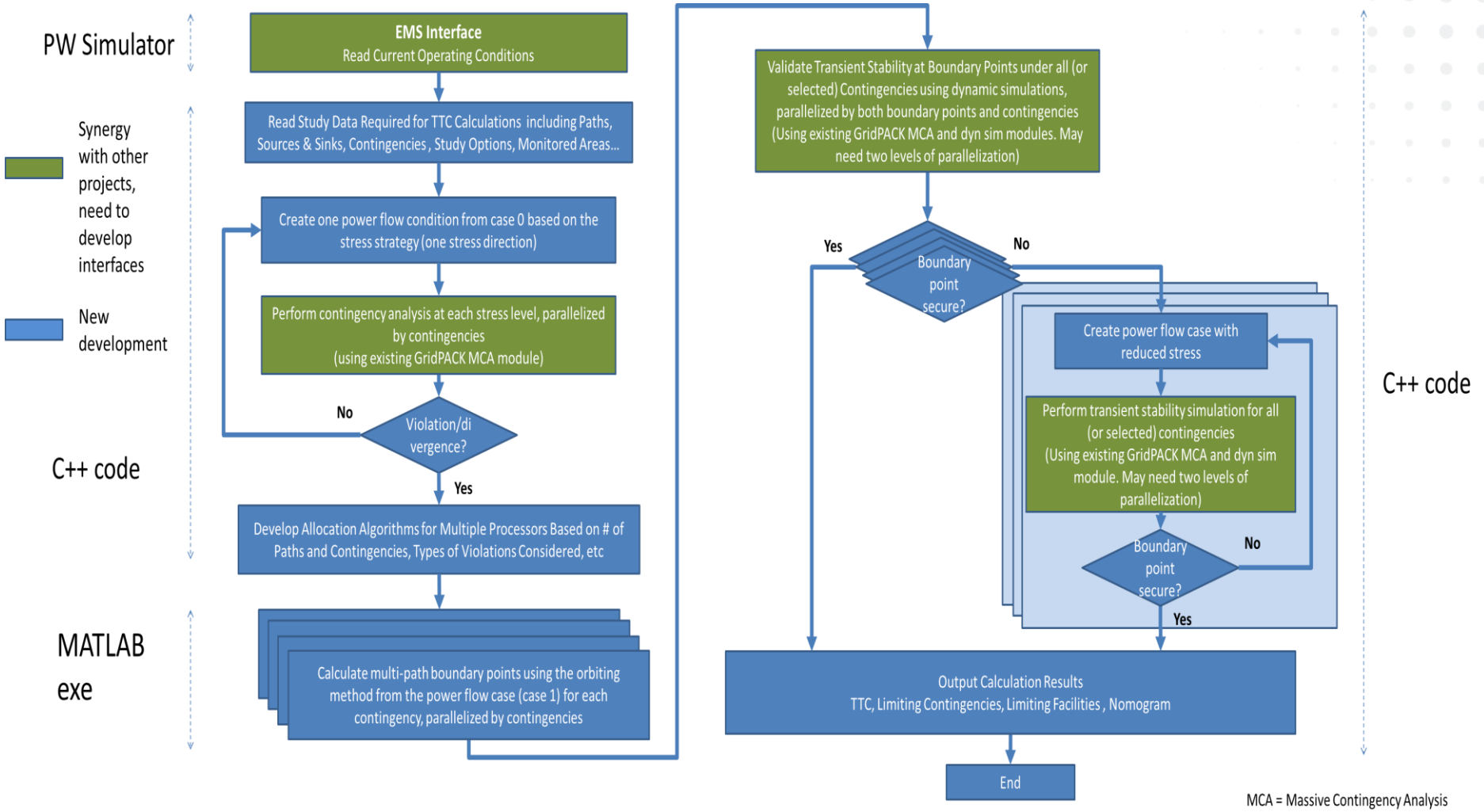

MCA = Massive Contingency Analysis

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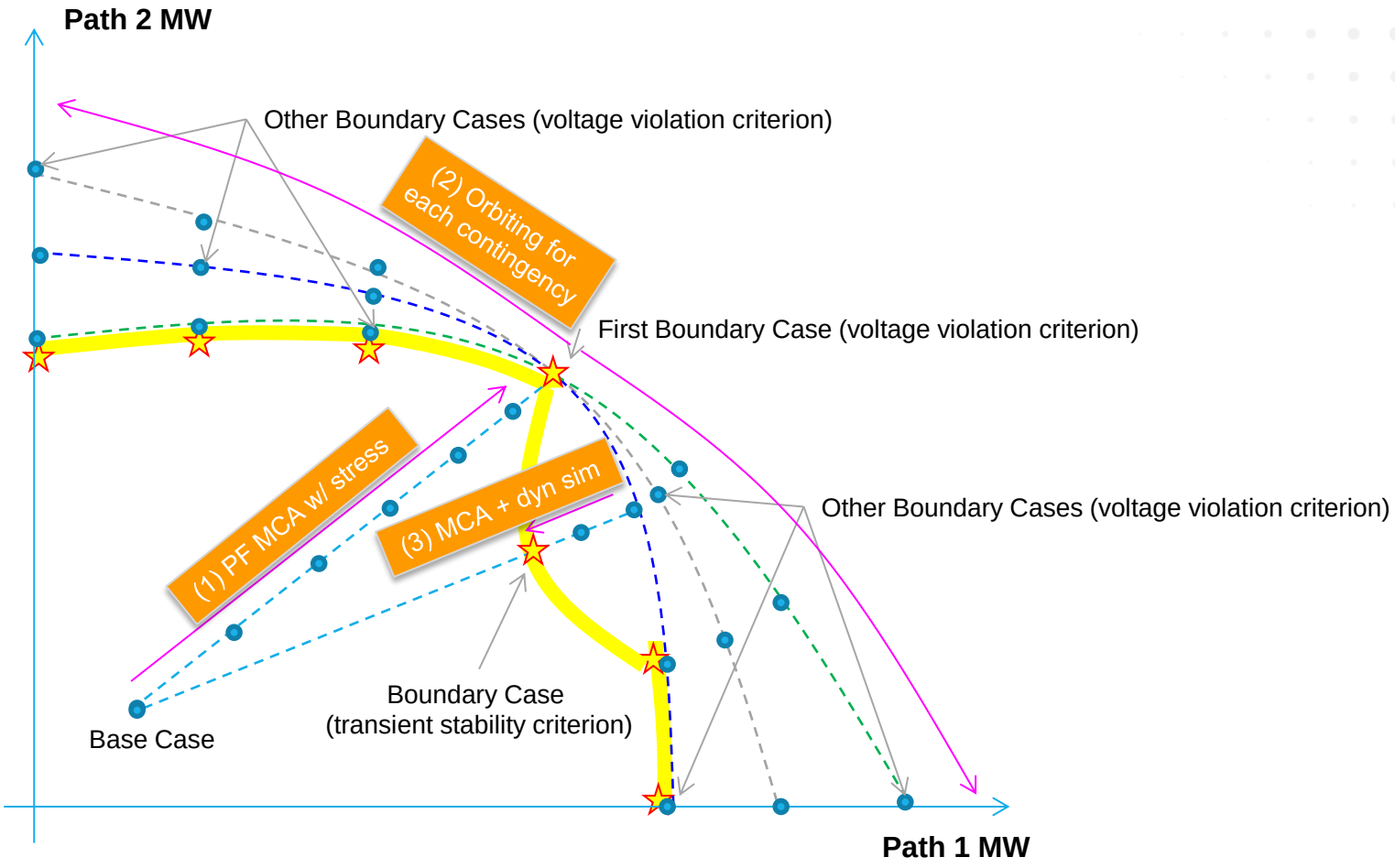
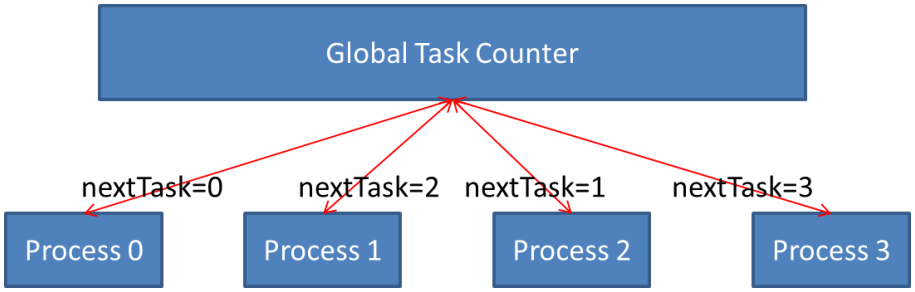
Two-Path Illustration of the Design



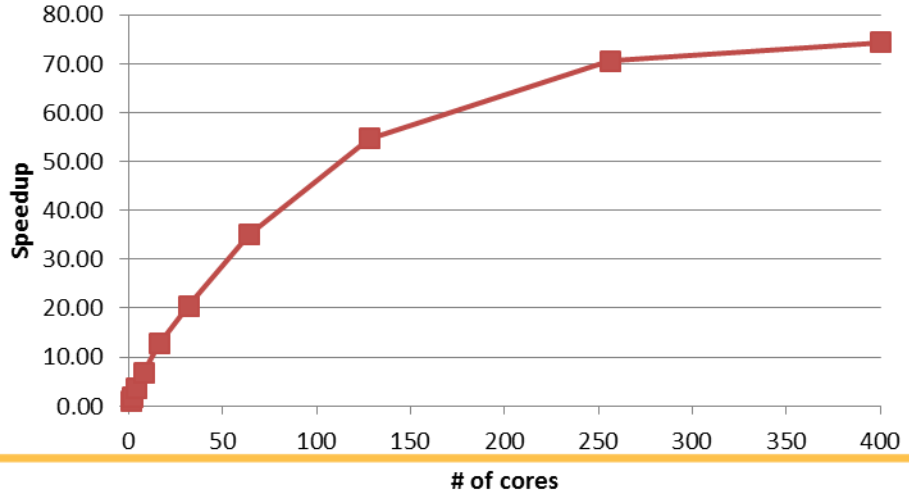
PF = Power Flow; MCA = Massive Contingency Analysis

Performance of Massive Contingency Analysis

- Idea: dynamically allocate massive contingency analysis scenarios to different processors based on their availability



- Implemented in GridPACK
  - Tested on a WECC base case
  - 400 contingencies
  - C++ based
  - Computational load balancing using a global counter



Performance of Parallel Dynamic Simulation

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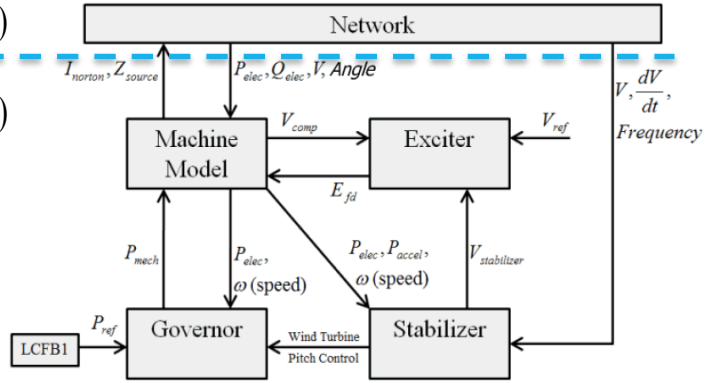
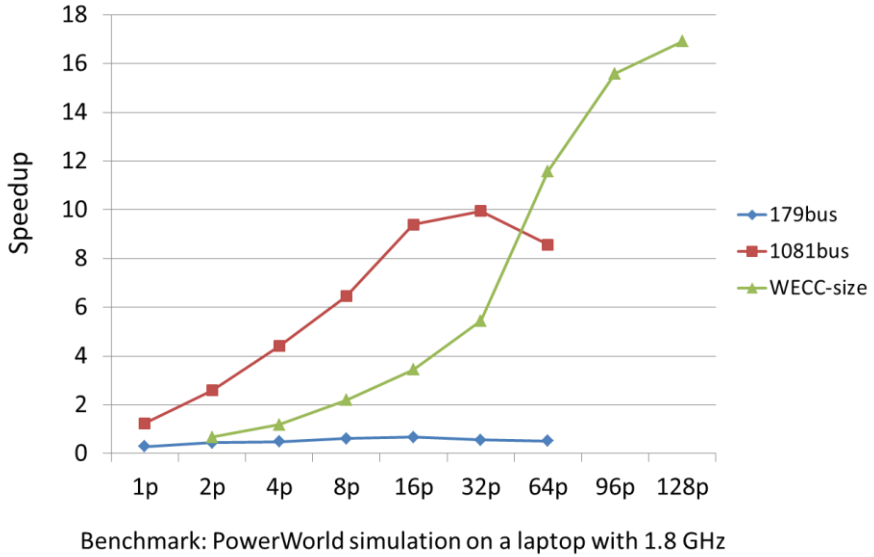
- Goal: Achieve 10x speedup over today's commercial tool
- Key algorithms:
  - Decoupled models for calculating states in parallel

$$0 = g(x, y)$$

$$\frac{dx}{dt} = f(x, y)$$





Benchmark: PowerWorld simulation on a laptop with 1.8 GHz

  - Identified KLU linear solver for solving network coupling

Fast Voltage Stability Simulation

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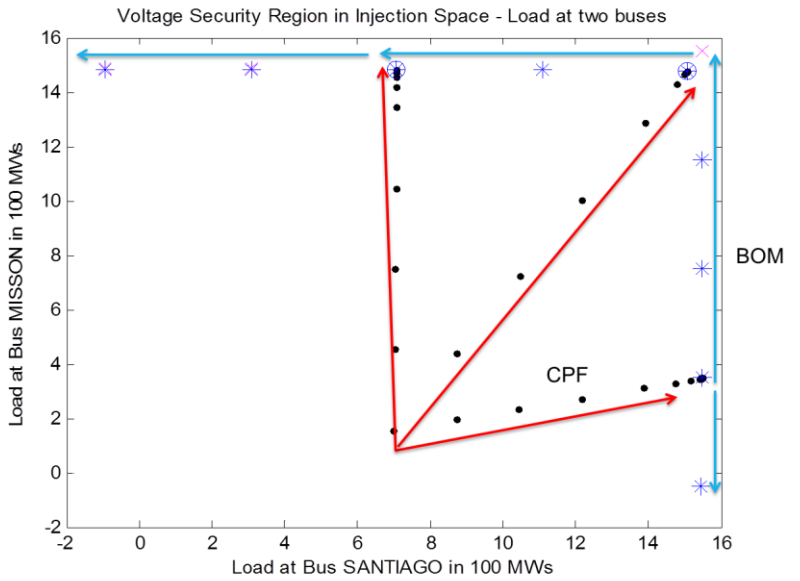
- Goal: Develop a non-iterative method to find voltage stability boundaries
- Developed and combined several methods
  - Continuation power flow
  - X-ray theorem
  - Orbiting method
  - High-order numerical method
- Accuracy validated against PW
- Only 9.5 s to find a new boundary point after initial point is identified for a WECC-size model



Summary of Speed Performance on a WECC Model using BPA procedures

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- Performance estimate of each key module for real-time path rating (Goal is 10 minutes):
  - To find the first boundary point (C++)
    - 12.7*8=101.6s considering 400 contingencies and 8 iterations, when using 400 processors
  - To find neighbor points using orbiting method (MATLAB)
    - 9.5*10=95 s for finding 10 points considering 400 contingencies using 400 processors
  - To verify transient stability for 5 contingencies
    - ~20s for running 5 dynamic simulations per identified boundary point (10 pts in total) using 400 processors
- Estimated total time = 101.6+95+20 + overhead=216.6s + overhead using 400 processors; roughly 433.2s+overhead if using 200 processors. The 10 minute goal is very well achievable on reasonable computing hardware.

Technology-to-Market

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- Initial product/market definition completed.
- Work presented at 2014 GENI meeting, 2014 APRA-E Summit, 2014 IEEE PES General Meeting, 2014 DOE AGM peer review meeting, and to Natural Energy Laboratory of Hawaii Authority (May 2014).
- All NDAs with advisors were signed.
- First Industry Advisory Board meeting held (July 2014) at Richland, WA: Four advisors attended the meeting, including Dede Subakti (CAISO), José Conto (ERCOT), Tony Johnson (SCE), and Slava Maslennikov (ISO- New England).

Conclusions

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- Transmission congestion is an ever increasing challenge, esp. with new generation and consumption of electricity.
- Real-time path rating could have major impact in congestion management and asset utilization improvement.
- Key simulation engines were successfully developed
  - Fast dynamic simulation
  - Fast voltage stability simulation
  - Massive contingency analysis simulation
- Progress to date indicates the 10 minute performance goal is very well achievable.

Questions?

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