arpa·e
CHANGING WHAT'S POSSIBLE

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

Robust Adaptive Topology Control

Mladen Kezunovic, PI
Texas A&M University

Kory W. Hedman, Co-PI
Arizona State University

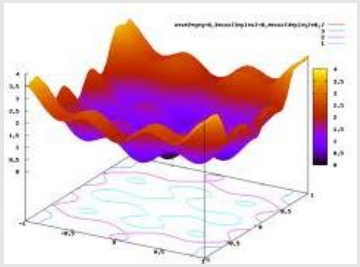
January 14-15, 2015

System Integration

- **Robust Adaptive Topology Control (RATC)** adds flexibility to system operations and can be used for a variety of purposes

Power Grid

Information Technology



Optimization

RATC Solution

Integrated Infrastructure

Outline

- Background
  - Phase II: Reliability Focus
  - Objectives and Demonstration
  - RATC Support Functions, Data Layer and Communications
  - Learning more about RATC
- Key Takeaway Points
  - Corrective RATC and Tool Development
  - Post-Contingency Corrective Transmission Switching
- Examples
  - Results: PJM Test Case
  - Results: ISONE

Phase II: Corrective RATC

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

Post-contingency corrective transmission switching

- Shortly after a contingency, take a line out of service (as a corrective action)
- Implement at most 1 corrective switching action
- But: identify multiple potential switching actions, in advance, per contingency to provide operators choice
- Perform stability studies to confirm switching actions

Objectives

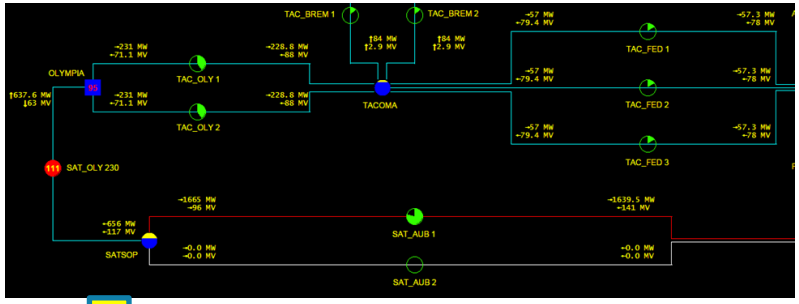
RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

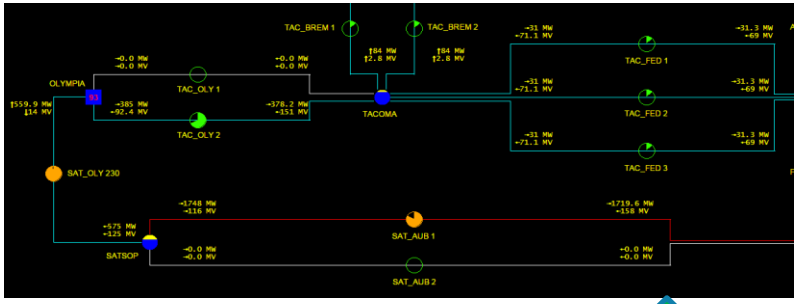
- Use demonstration example to compare current needs and RATC benefits:
  - AC based
  - HPC multi-core, multi-thread capable
  - Open source
- Assure topology control:
  - Stability
  - Monitor breaker reliability and associated switching risk
  - Adjust relay settings
  - Have reliable indicators for a need to switch lines
  - Analyze communication requirements

Demonstration Example

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

- Uses PowerData's generic Cascadia model within the PowerSimulator
- Demonstrates RATC within the Contingency Analysis process using IncSys Training Scenarios





RATC

Line	Flow	LODF	Order
TAC_OLY 1	-228.40	0.50	-114.20
TAC_OLY 2	-228.40	0.50	-114.20
TAC_FED 1	57.57	-0.33	-19.19
TAC_FED 2	57.57	-0.33	-19.19

arpa·e
CHANGING WHAT'S POSSIBLE

RATC Support Functions

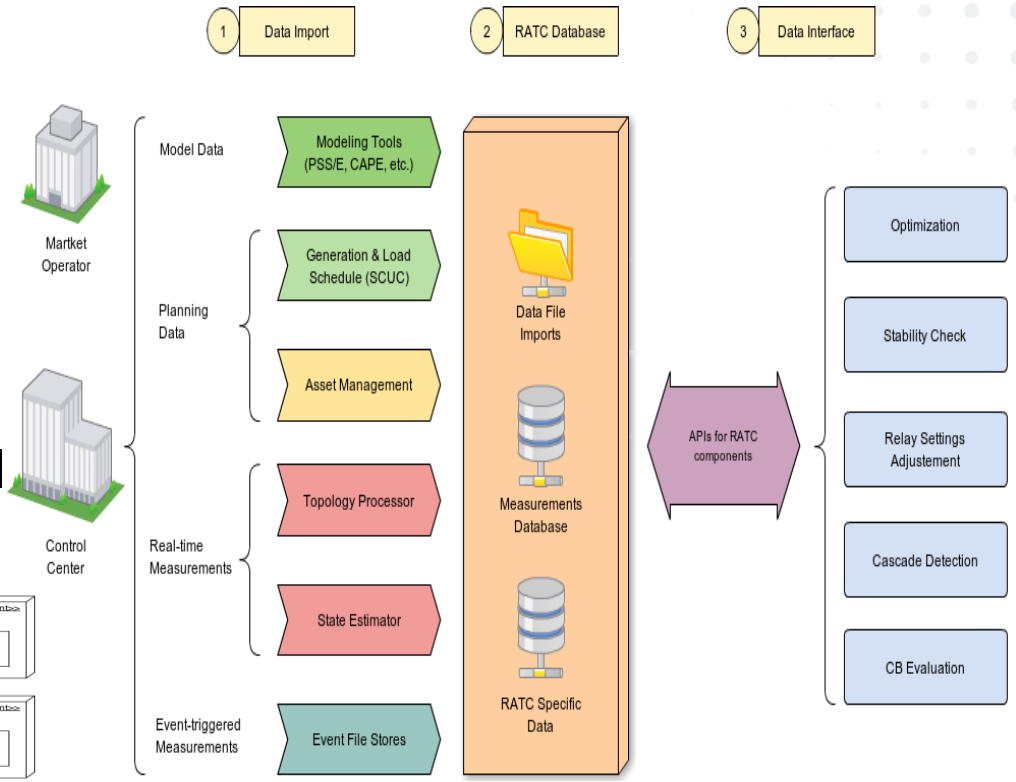
RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

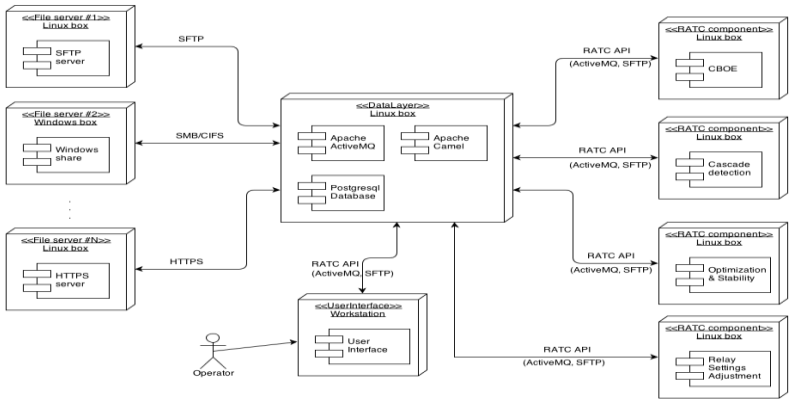
- Relay Mis-operation Detection
  - Fault confirmation
  - Mis-operation detection
- Circuit Breaker Operation Evaluation
  - Circuit breaker health assessment
- Relay Setting Coordination Check
  - Relay settings evaluation
  - Relay coordination check

RATC Data Layer

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

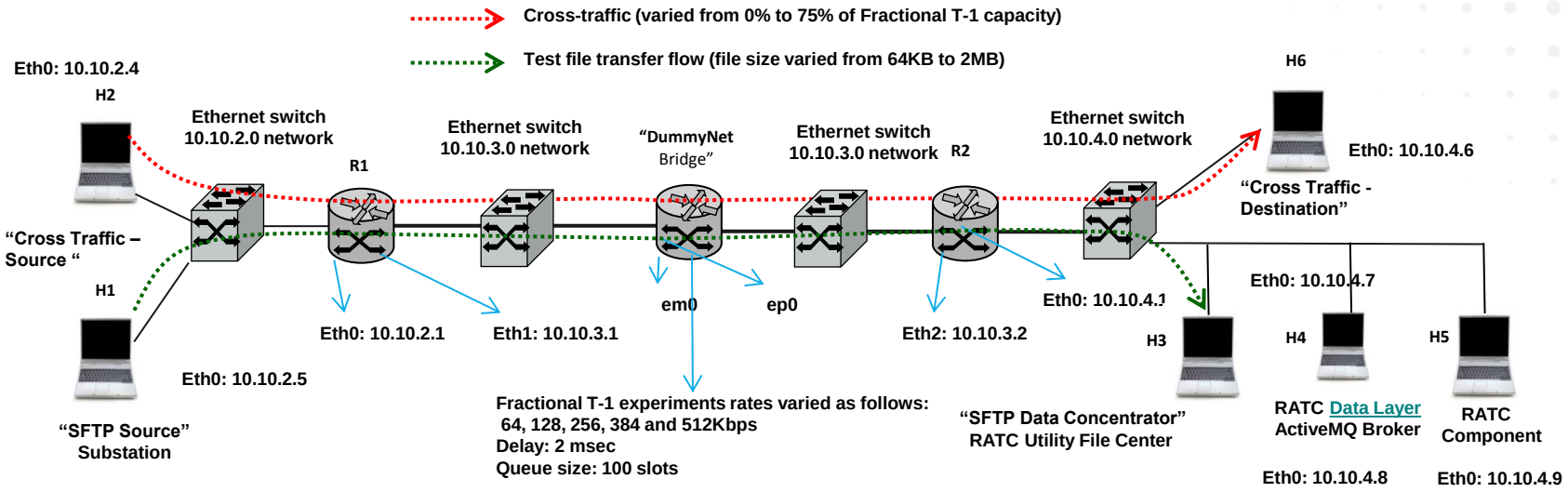
- Supports data flows between RATC components and external data sources
- Provides reliable data storage and retrieval services
- Provides API to RATC components to obtain data
- Based on the Apache Camel Framework





CHANGING WHAT'S POSSIBLE

Communication Environment



Model of RATC system elements:

- H1 – Substation,
- H3 – Control Center (CC) Data Concentrator (RATC Utility File Center),
- H4 – RATC Data Layer, and
- H5 – RATC Component.

Learning more about RATC

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

- Full RATC Demonstration
  - ARPA-E Technology Showcase
    Feb 10-11, 2015, Booth 528

- RATC User Forum: The ISONE Experience
  March 12, 2015
  - @ FERC - 888 First Street, NE, Washington, DC 20426
  - Full RATC Demonstration
  - Report of RATC performance at ISONE

How do I get RATC details? smartgridcenter.tamu.edu/ratc

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

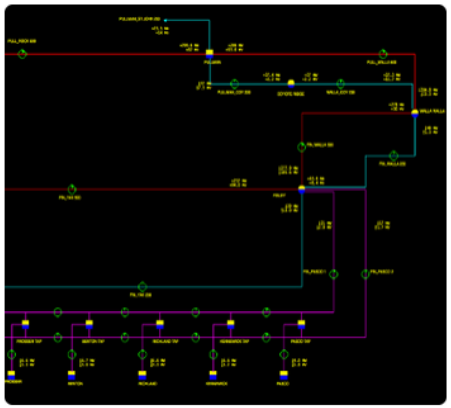
Home | Technology | Events | Use Cases | Toolset | People | Partners | Publications | Contact

Welcome!

Robust Adaptive Topology Control (RATC)

A fresh look at topology control for power grid contingency management: the RATC toolset enables utility operators to identify topology control options for addressing contingencies and renewable intermittencies.

Learn more



Mission

Develop technologies to enable utilizing the system's existing infrastructure with the topology control as a mechanism to improve system operations via post-contingency corrective transmission switching.

Vision

Robust adaptive topology control advances the power grid by modifying existing energy and market management systems to provide the operator with an additional control mechanism to prevent and mitigate post-contingency violations.

Key Takeaway Points

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

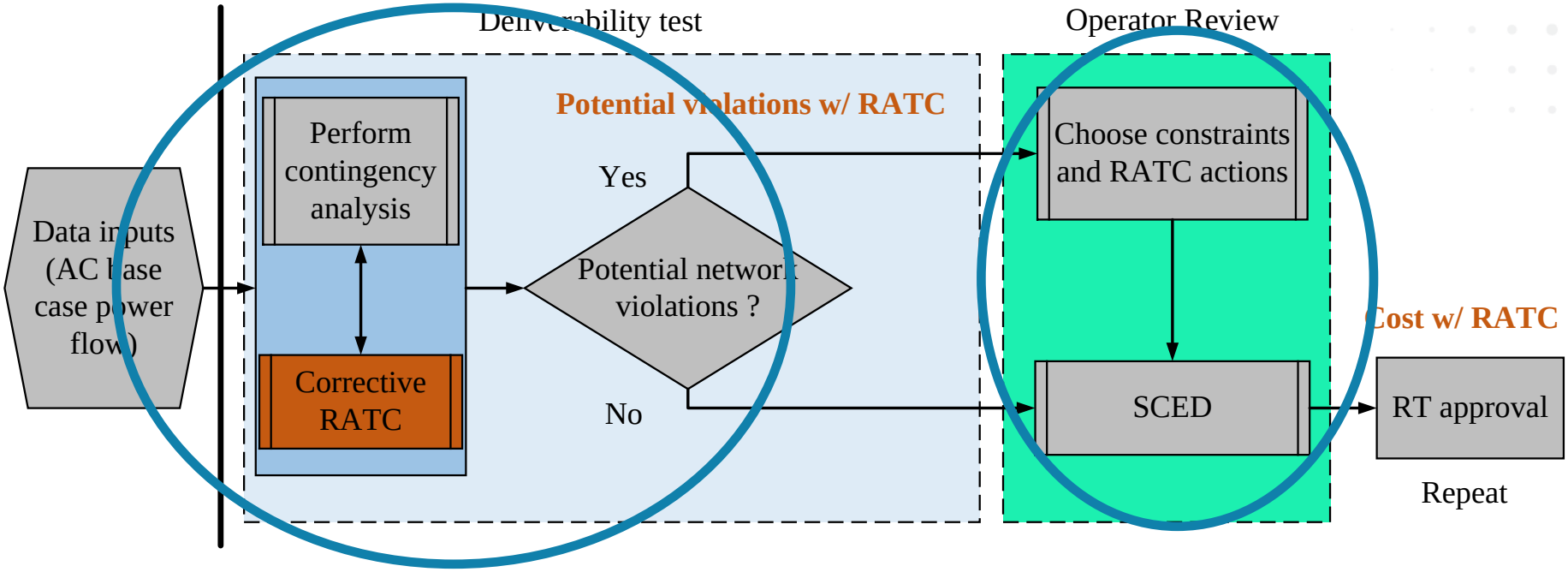
- Limited modeling of flexible transmission assets (lines, transformers, FACTS) within EMS & MMS
- Future EMS and MMS will co-optimize flexible transmission with generation
- This presentation focuses on **post-contingency corrective transmission topology control**
- Future goal: expand to capture FACTS

RTCA Tool Development

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

- Multi-threaded HPC base AC Power Flow Real-Time Contingency Analysis Package (RTCA) with Corrective Switching
- Open Source
- Expanded Dr. Robin Podmore's Open Source AC Power Flow tool to create multi-threaded RTCA package

Corrective Switching with Real-Time Contingency Analysis



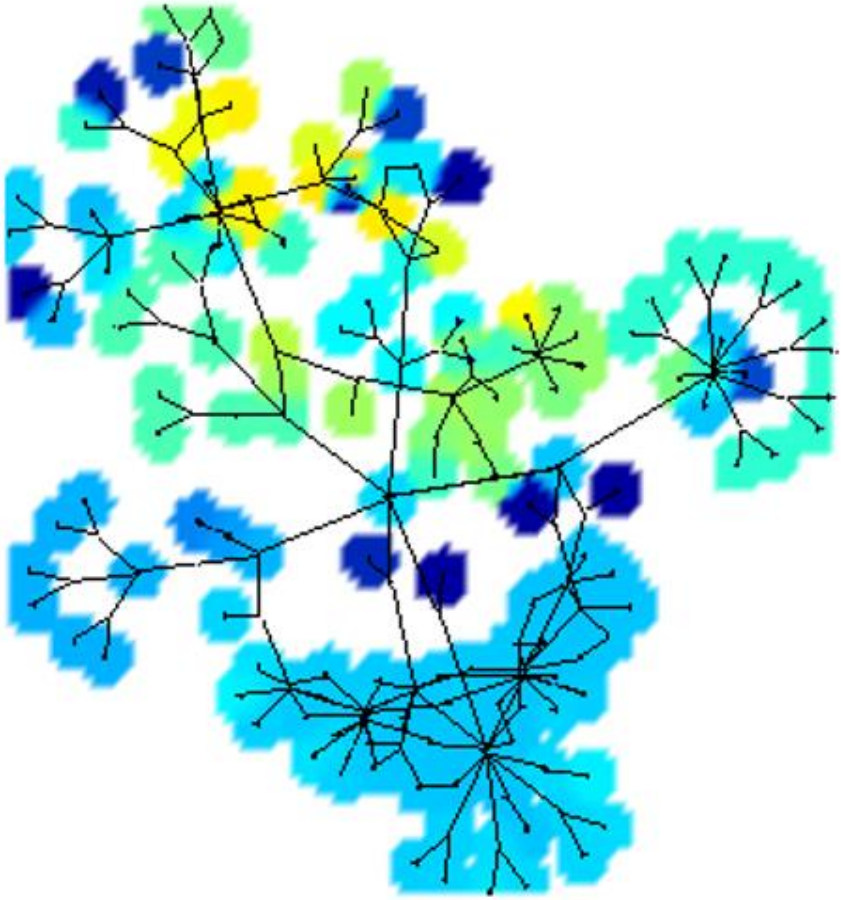
Corrective RATC determines corrective transmission switching actions

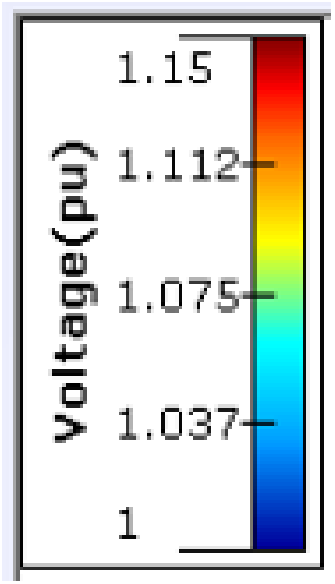
Constraints sent to SCED are reduced; operational costs decrease; reliability maintained

Example: Pre-Contingency State

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

Subsection of an actual large-scale system



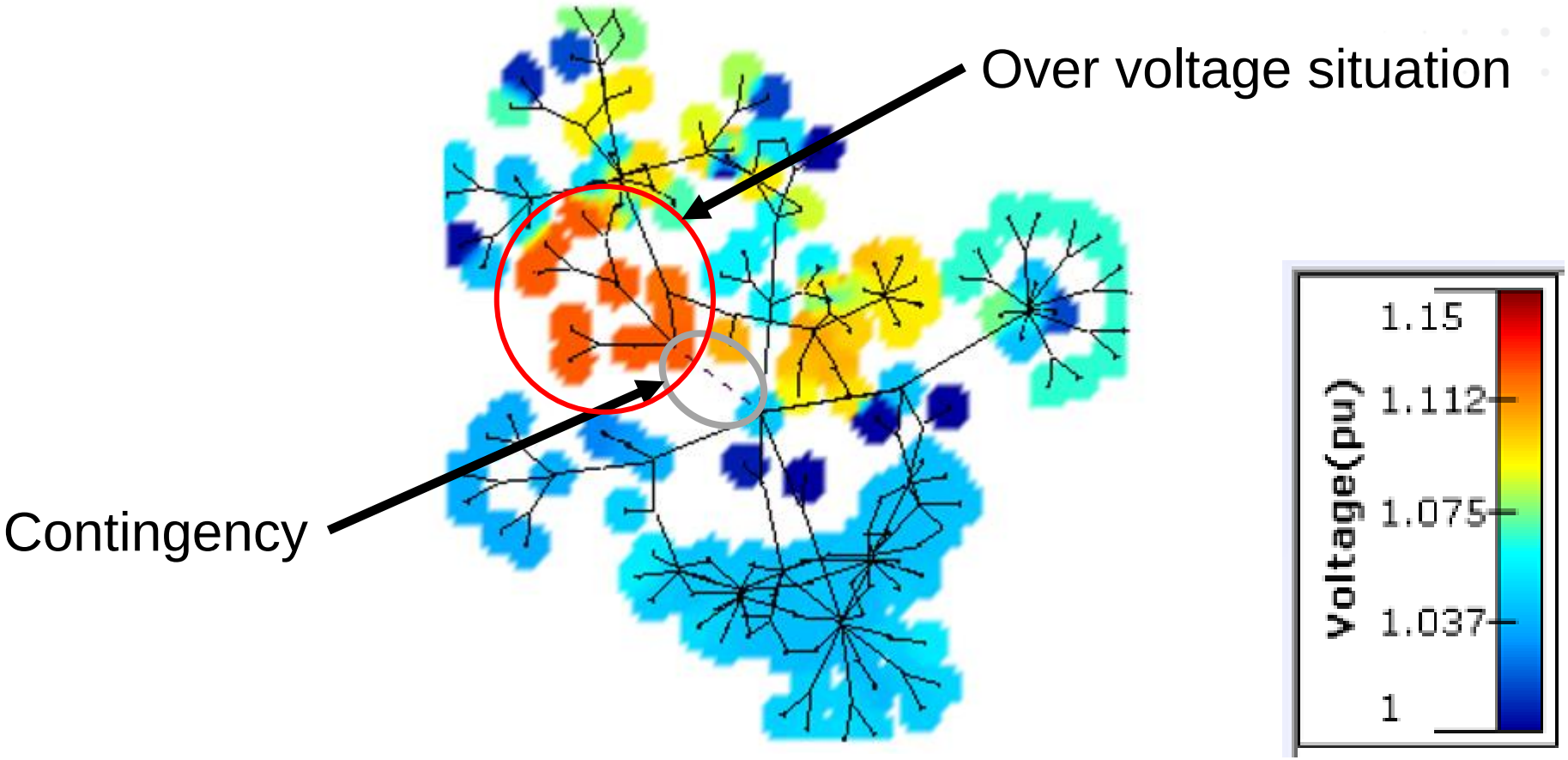


All 500 kV buses

arpa·e
CHANGING WHAT'S POSSIBLE

Post-Contingency State

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL



All 500 kV buses

arpa·e
CHANGING WHAT'S POSSIBLE

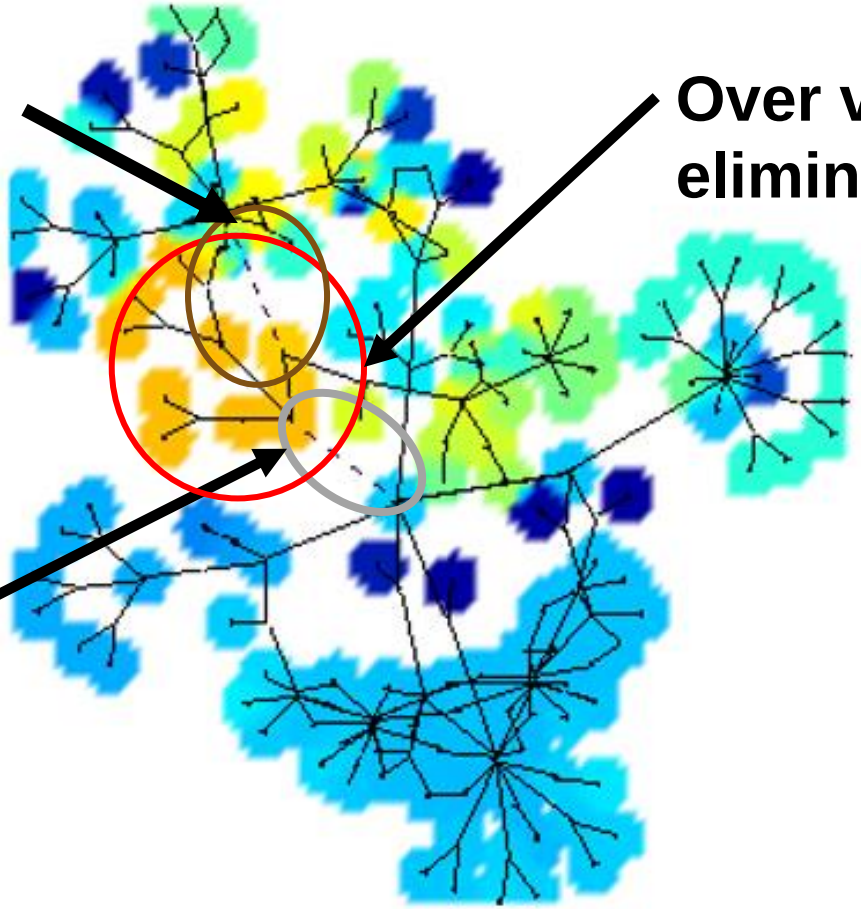
Post-Contingency State with RATC

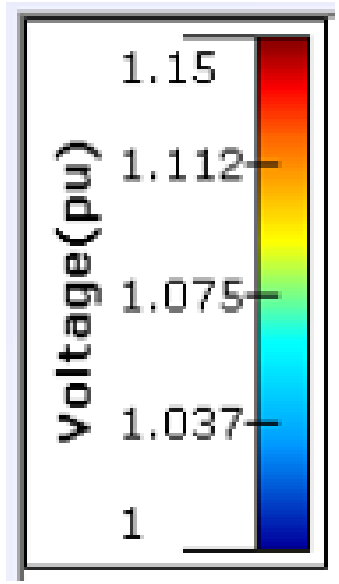
RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

Topology control solution

Over voltage situation eliminated

Contingency





All 500 kV buses

Test Data Source: PJM

- Tool takes PSS/E .RAW files as inputs
- 167 PSS/E .RAW input files based on PJM data for testing (7 days)
  - **Actual real-time operational snapshots from PJM**
- Network
  - ~15,000 buses; ~20,500 branches; ~2,700 gen; ~1,600 switchable shunts; ~8,900 contingencies

Corrective RATC Benefits

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

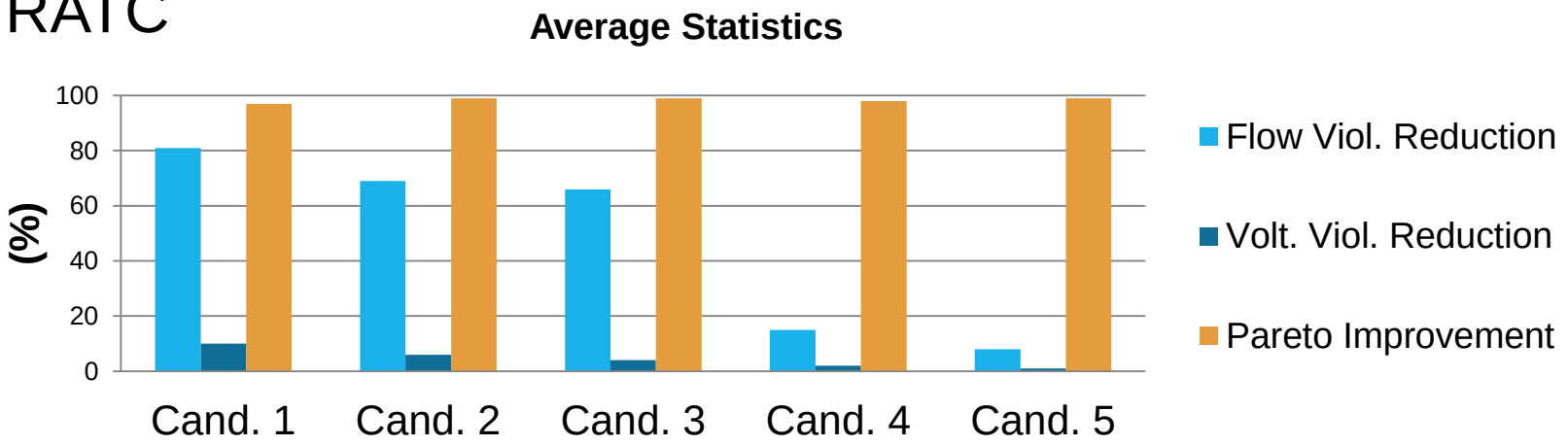
Tolerance: *V violation > 0.005 pu or MVA violation > 5MVA*
For single corrective switching actions:

- Number of contingencies with violations outside of tolerance: **4726**
  - (contingencies with violations that are evaluated)
- # of contingencies where there is **NO beneficial** corrective switching action:

10 cases: ~0.2%

RATC-Based RTCA for PJM

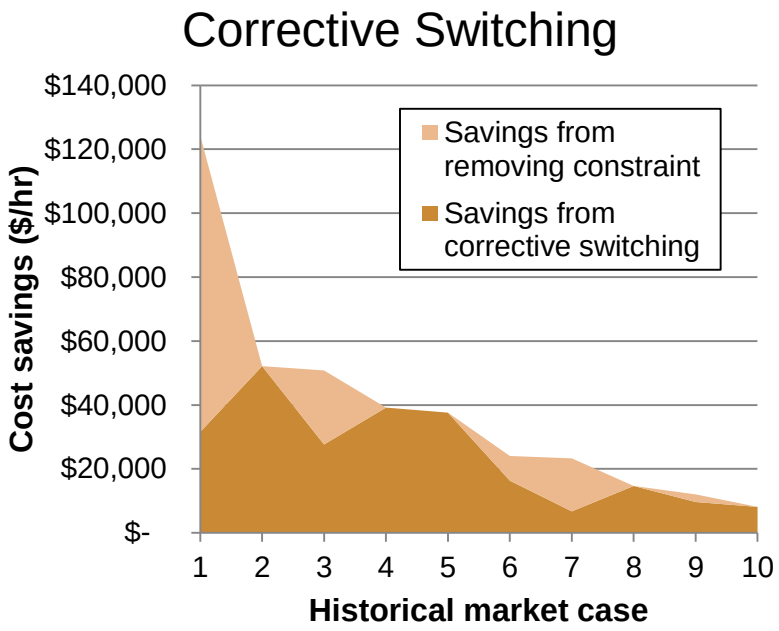
- # of contingencies with violation: **4726**
- Out of **4726** contingencies with violations (passed to corrective RATC), **52% (2476)** of contingencies have no violation with corrective RATC **(2nd best candidate: 43%)**
- Out of **4726** contingencies with violations (passed to corrective RATC), **67% (3190)** of contingencies have violations within the specified tolerance with corrective RATC



19

Collaboration with ISO-NE

- Ongoing investigation with ISONE
- For cases where congestion exists, there has always been a transmission switching action that provides a benefit



20

Questions

RATC
ROBUST ADAPTIVE TOPOLOGY CONTROL

Contact:

Mladen Kezunovic
kezunov@ece.tamu.edu, 979-845-7509

Kory W. Hedman
khedman@asu.edu, 480-965-1276