Real-Time Applications Using Linear State Estimation Technology

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Introduction

Electric Power Group (EPG) has developed three real-time applications using Synchrophasor data and Linear State Estimation technology: **Synchrophasor Based Real-Time Contingency Analysis** (RTCA), **Voltage Stability Assessment**(VSA) and **Area Angle Monitoring** (AAM). RTCA assesses system stability and alerts operators to potential violations based on user-defined contingencies. VSA assess the voltage stability of the system, alerts operators to potential voltage collapse and recommends corrective actions. AAM uses an area angle to monitor the power flow stress across a specific area.

Synchrophasor Based Real-Time Contingency Analysis (RTCA)
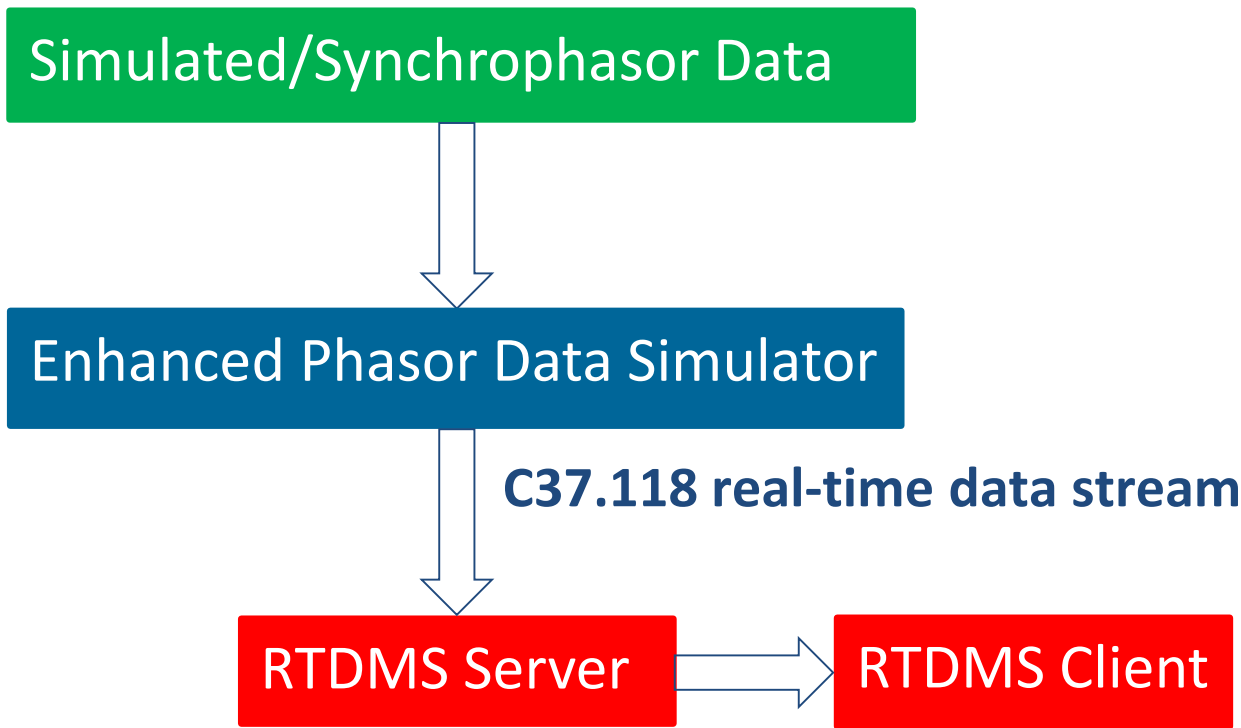
- **Benefits of RTCA**
  - Study what if contingency scenarios to assess system violations
  - Apply each contingency & readjust power flows
  - Check for violations of power flow and bus voltage limits
  - List violations and send alerts based on violation level
  - Grid Resiliency – Improve Situational Awareness, Actionable Intelligence, Based on *e*LSE which always solves, Provides Backup to conventional RTCA

- **Key Functions of RTCA User Interface**
  - High-level view of key results and most severe violations
  - Drill down views for individual contingency results
  - Real-time Mode vs Manual Study Mode
  - Resolution independent rich UI developed using Microsoft Windows Presentation Foundation (WPF)
  - Historical trend – overview of previous results
  - User configurable settings – time interval for execution, retention settings for storing data, results, cases
 - Alert/Indicators when no results, in case of errors

- **RTCA Visualization**
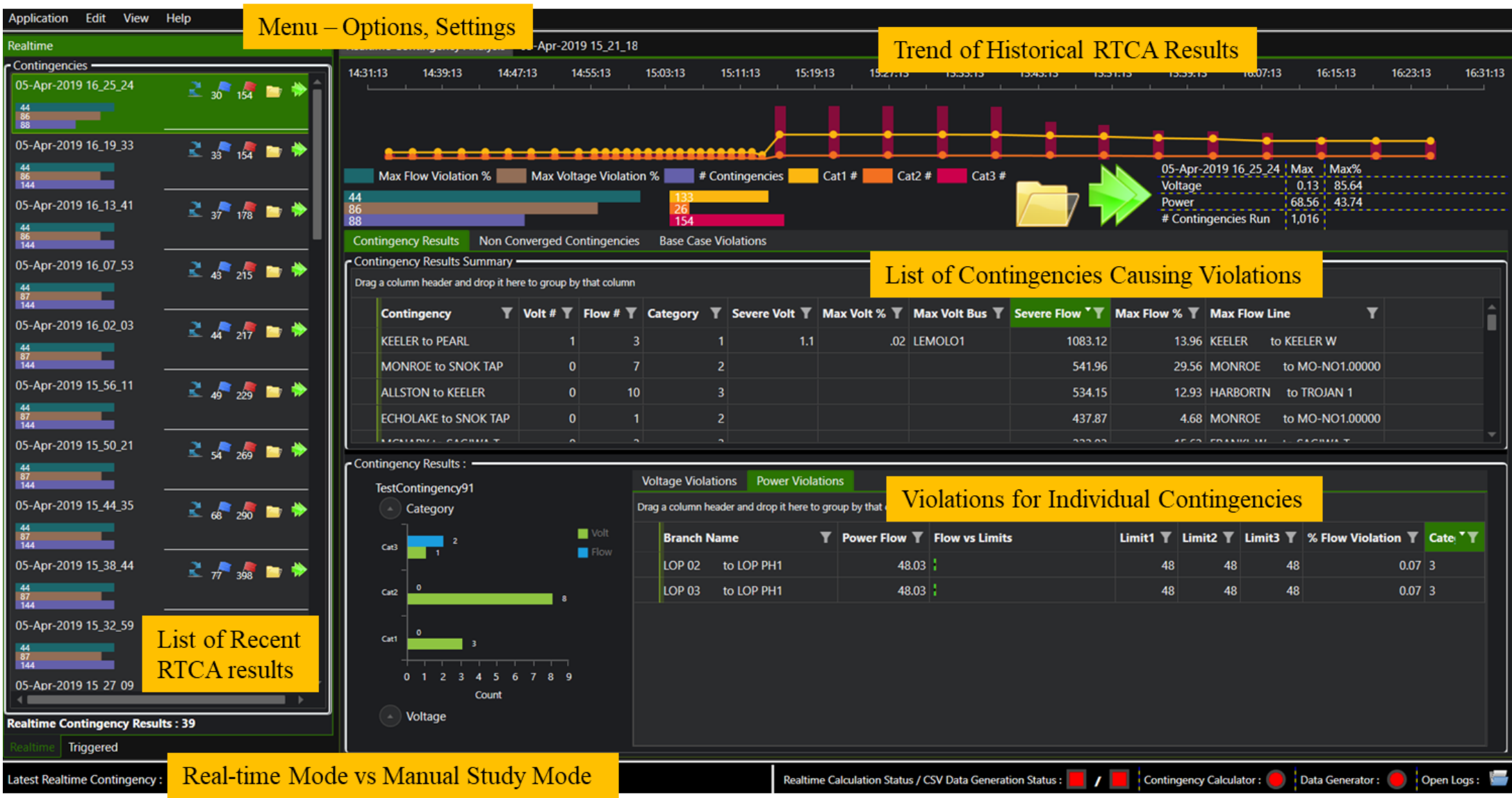
Area Angle Monitoring (AAM)

- **Basic Concept of AAM**

Study area

R — Ma, Mb

Area angle

$$\theta_{area} = \sum_{i=1}^{M_a} w_i \theta_i + \sum_{j=1}^{M_b} w_j \theta_j$$

$$\sum_{i=1}^{M_a} w_i = 1, \sum_{j=1}^{M_b} w_j = -1$$

Area angle threshold

$\theta_{area} \ge \theta_{thr}$ → **Alarm**

$\theta_{area} < \theta_{thr}$ → **No alarm**

Warning threshold
Emergency threshold

- **Benefits**
  - Use area angle to observe the power flow stress across an area
  - Use synchrophasors for real-time monitoring of grid stress
  - Provide situational awareness and actionable intelligence to system operators

- **Simplified Data Flow of AAM – Testing & Demonstrations**

Simulated/Synchrophasor Data

↓

Enhanced Phasor Data Simulator

↓ **C37.118 real-time data stream**

RTDMS Server → RTDMS Client

- **Visualization of AAM on RTDMS Client**
  - Monitor an area covering Oregon in Bonneville Power Administration (BPA)
  - Contingency: Loss of lines of John day–Grizzly #1 and #2 and Grizzly–Malin
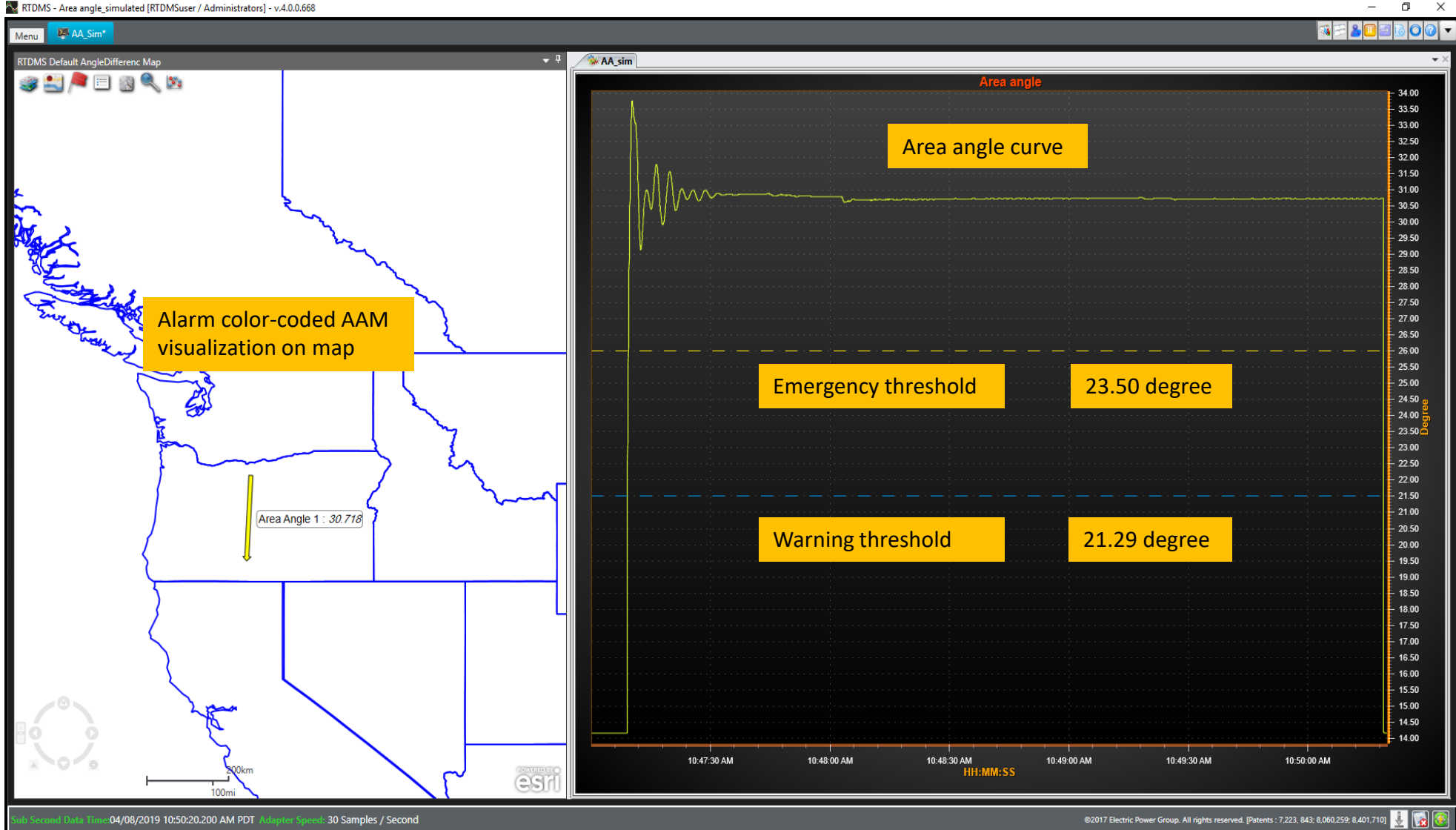
Voltage Stability Assessment (VSA)

- **Benefits**
  - Perform Voltage Stability Assessment in real-time using synchrophasors and *enhanced* Linear State Estimator (*e*LSE)
  - Provide a timely indication to operators when approaching voltage instability so they can take action to restore it

- **Methodology**
  - Reduce multiple lines of transmission corridors to a single line using synchrophasor measurements of complex power and current at each end of each line in the transmission corridor
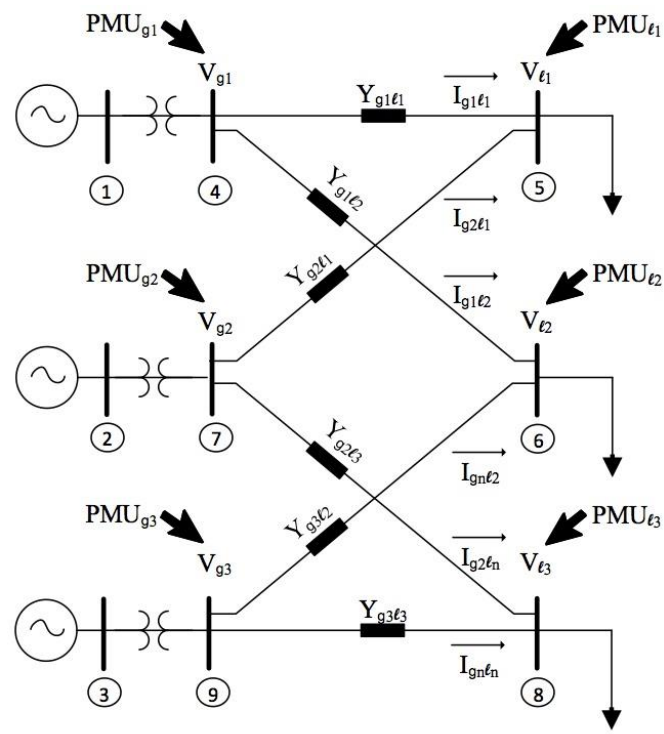
- **Visualization of VSA on RTDMS Client**
  - Monitor the transmission corridor of Grizzly-Malin in BPA system

Conclusion and Future Work

- Developed three real-time applications using synchrophasors and LSE
- Implemented and demonstrated them for BPA systems
- These applications will be implemented to New York Power Authority (NYPA) and Duke Energy
- ***Future Work: Cascading Analysis***

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