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# **Grid Transformation Workshop**

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# Probabilistic Planning – What to Include?

- Accurate modeling, including model and data exchanges across interconnection
- Incorporating operational experiences
- Infrastructure correlation and priorities

- Gas – Electric interaction

- Telecom – Electric

- Aging assets and Storm hardening

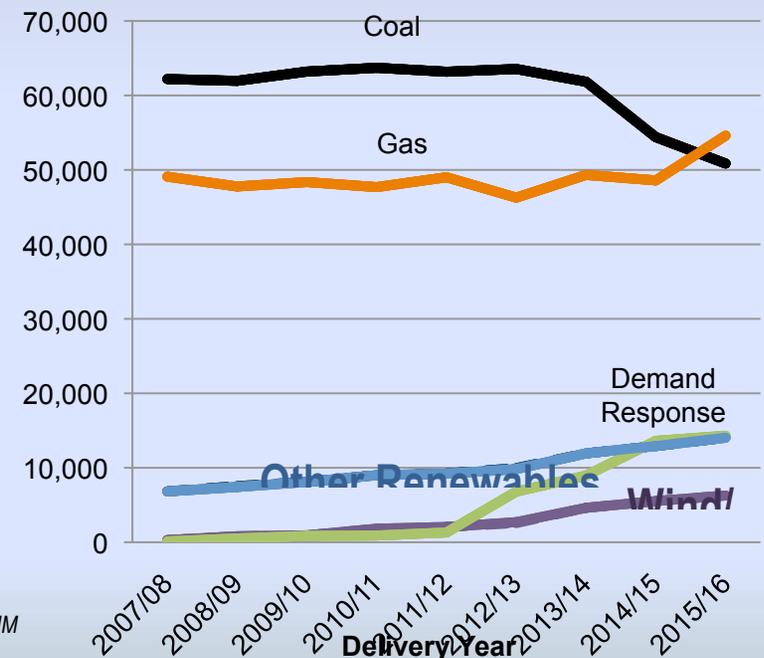
- Critical substations

- Cyber security

- SIPS management

- EV and Storage

- ...



Source: PJM



# Defense in Depth Approach

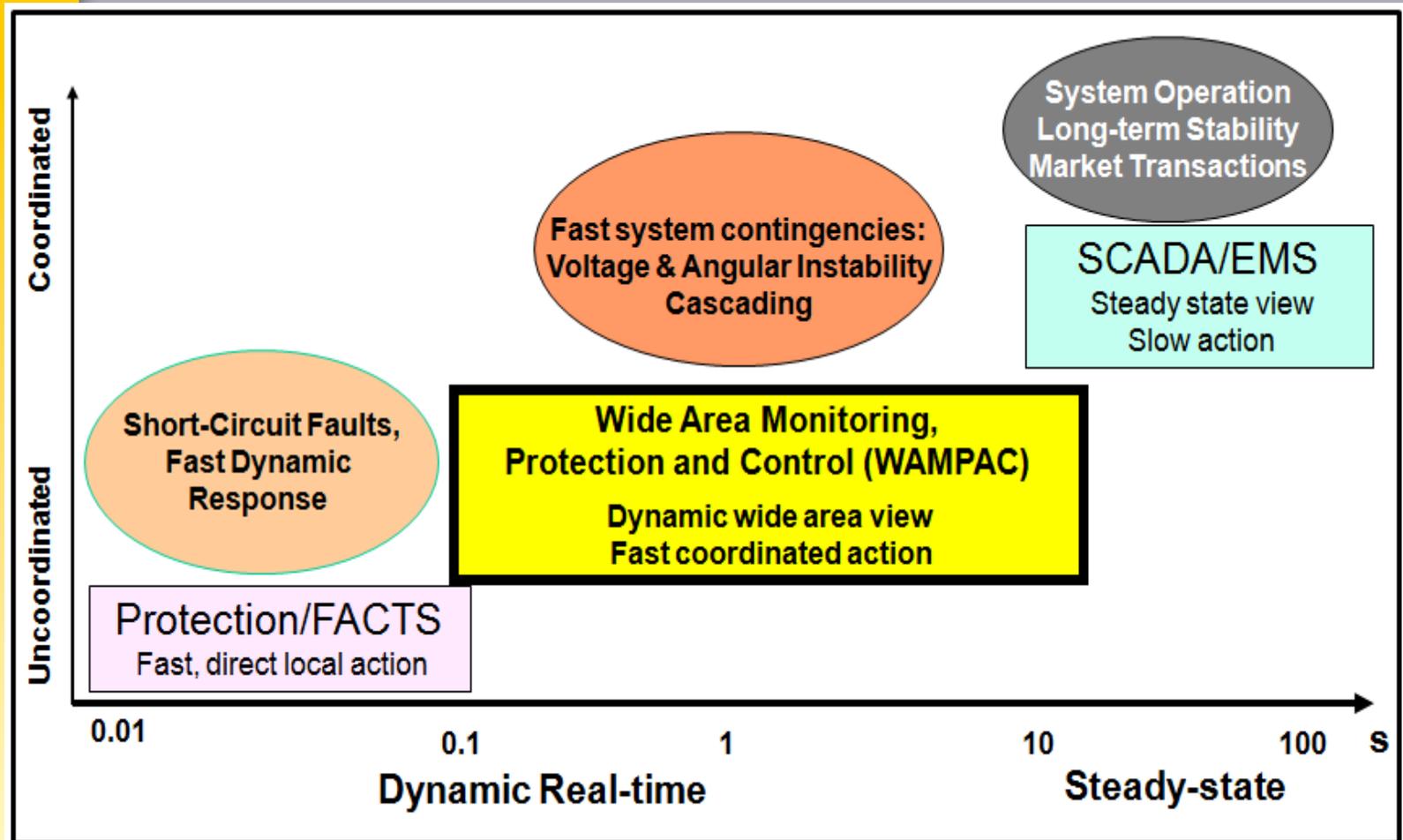
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- **Primary:** Reliability starts with good planning
  - ... But actual system conditions are often different from what is planned
  - ...
- **Secondary:** State estimator based real time contingency analysis
  - ... But, your model may be wrong (model errors, control failures, etc) ...
- **Tertiary:** Intrinsic indicators > operating alarms and safety nets
  - **Safety nets** designed to protect against extreme unplanned events or FIDVR-type events when model is not certain
  - Could be viewed as a liability (poorly designed scheme can cause unnecessary loss of load, NERC CIP paperwork, etc)
  - What is the place for safety nets?
- **Wide Area Monitoring, Protection, and Control Vision**



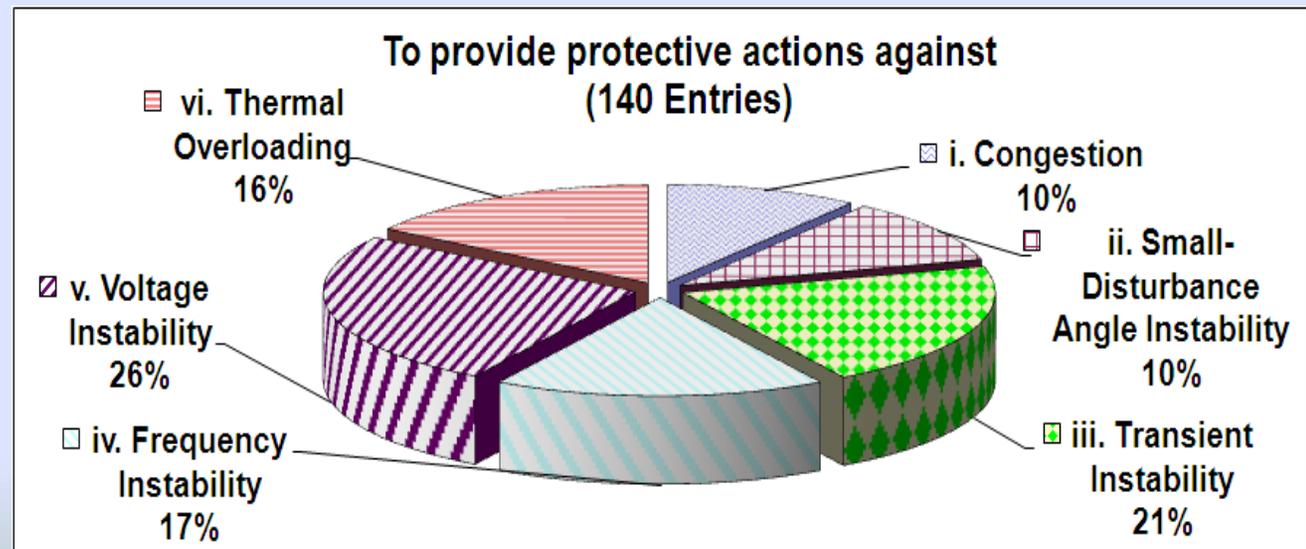
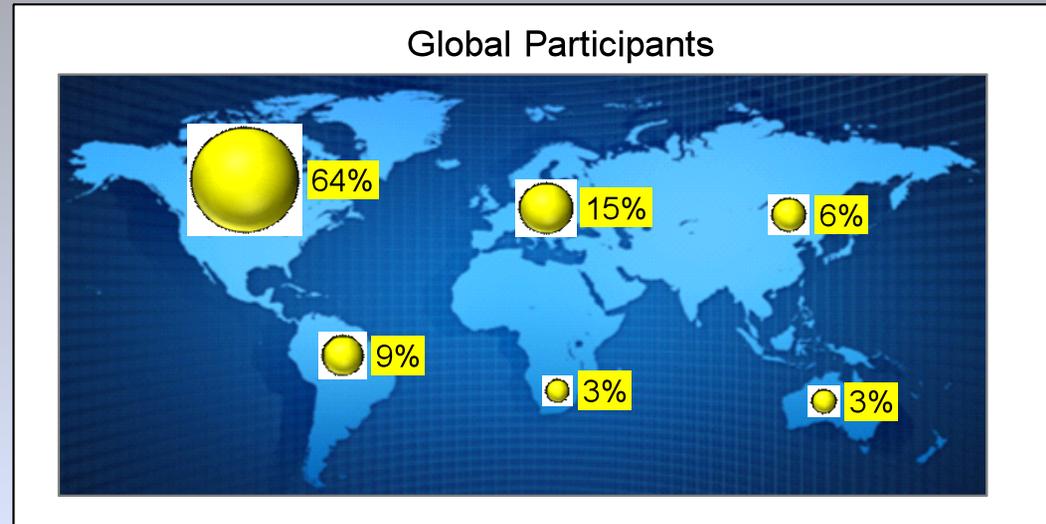
Source: Dmitry Kosterev, BPA

# WAMPAC Vision



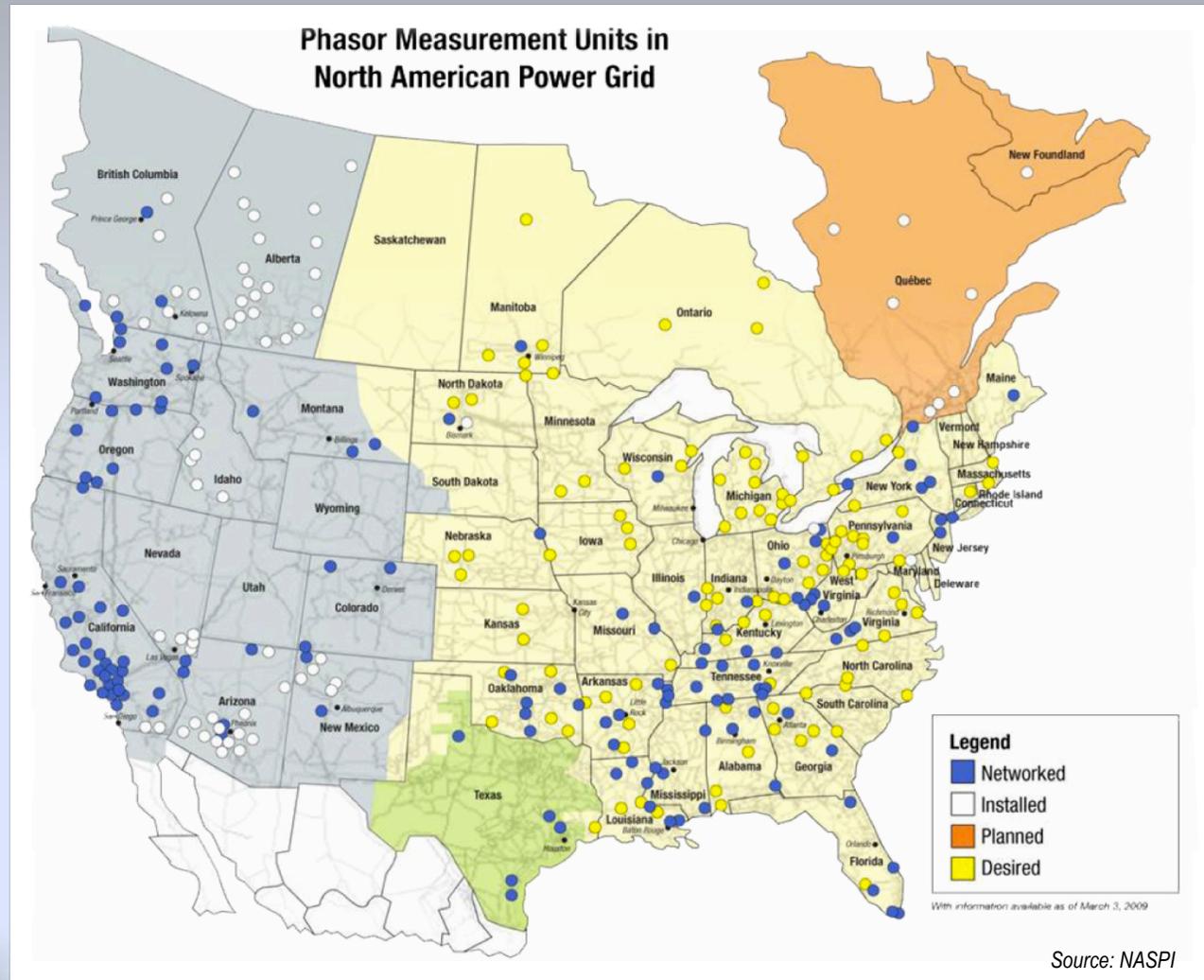
# Experiences with SIPS

IEEE PSRC  
Report - 2009



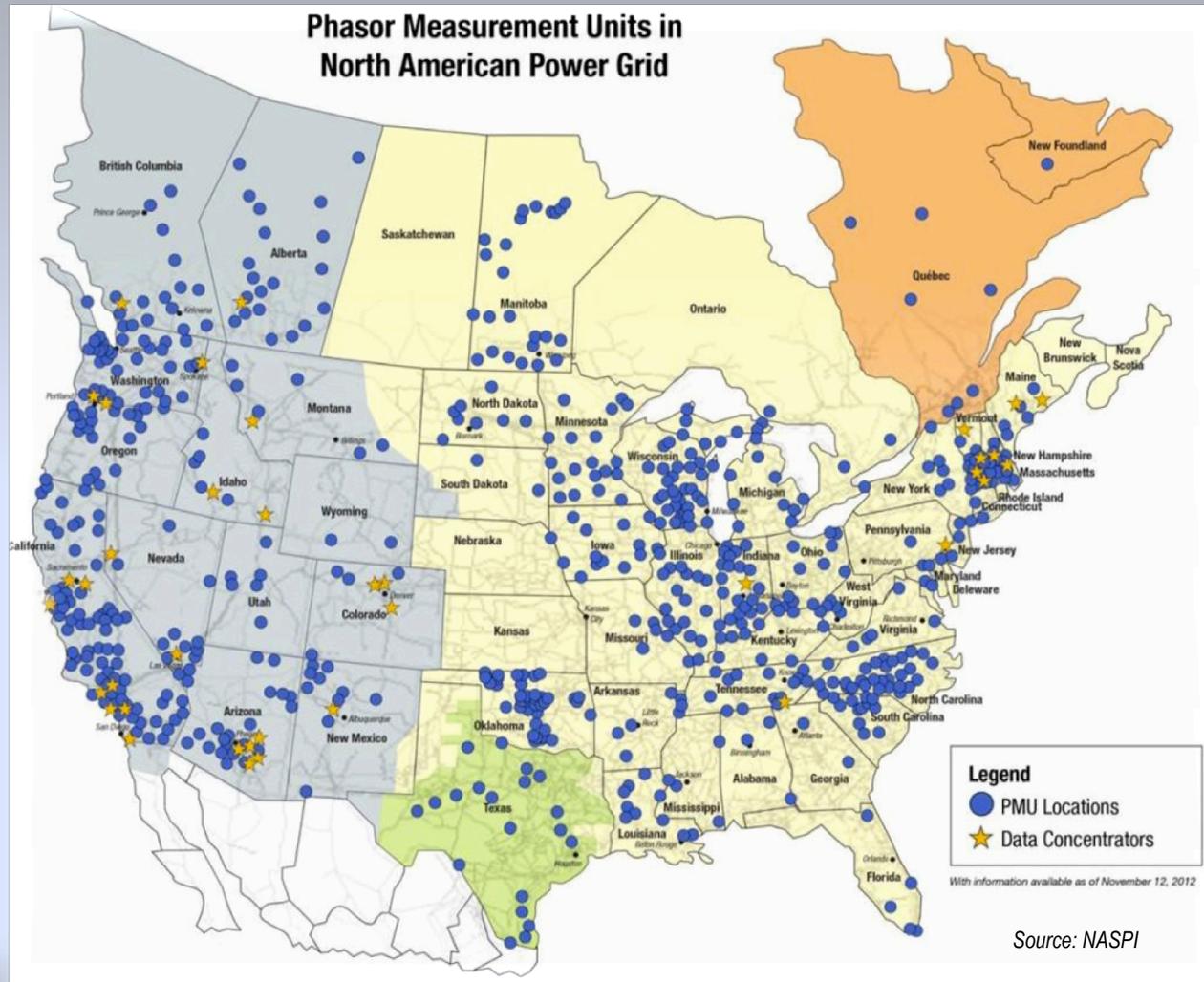
# PMU Deployment

## U.S. and Canada 2009

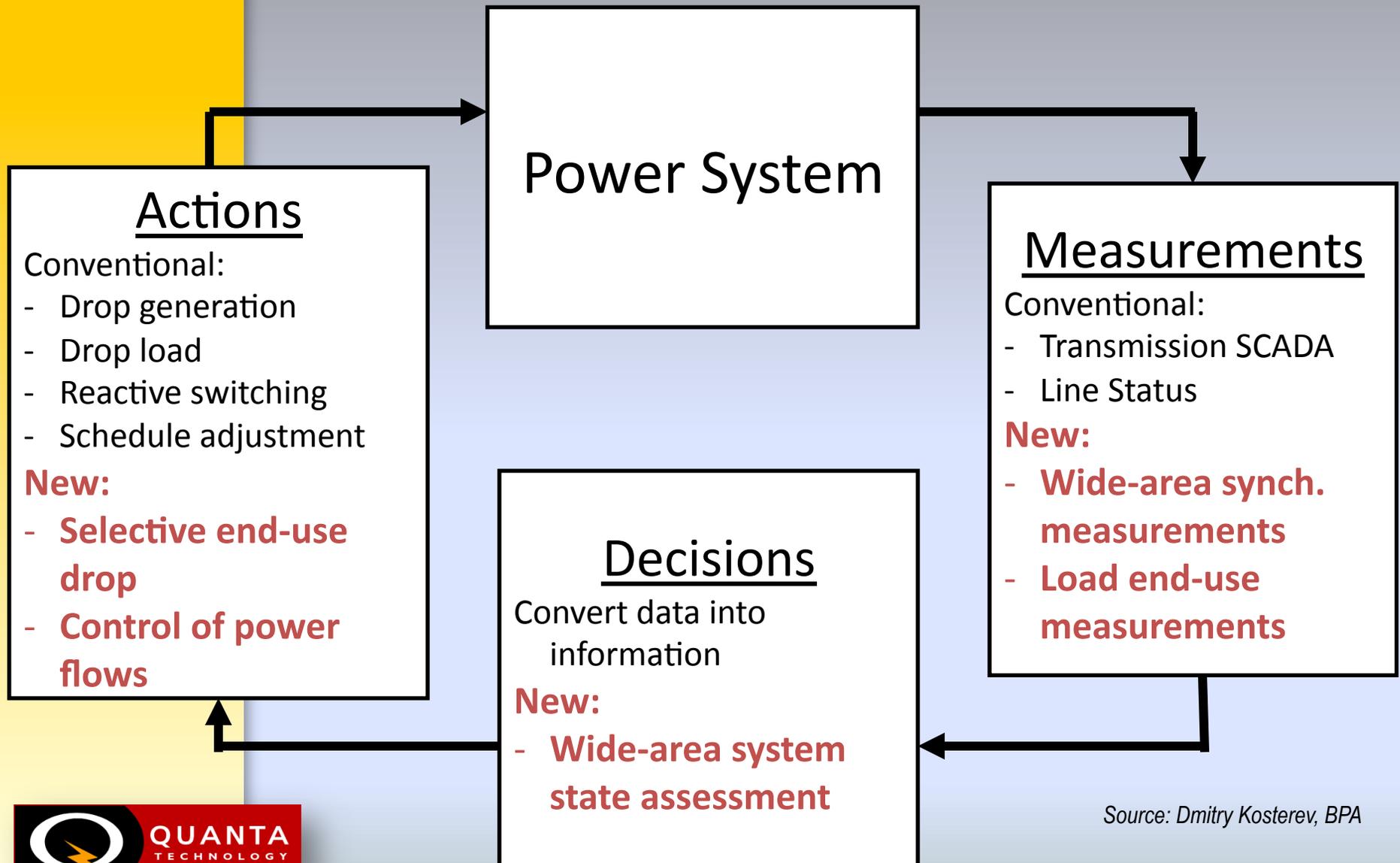


# PMU Deployment

## U.S. and Canada 2012



# Wide Area Controls Vision



Source: Dmitry Kosterev, BPA



# WAMPAC Progression

**Before**

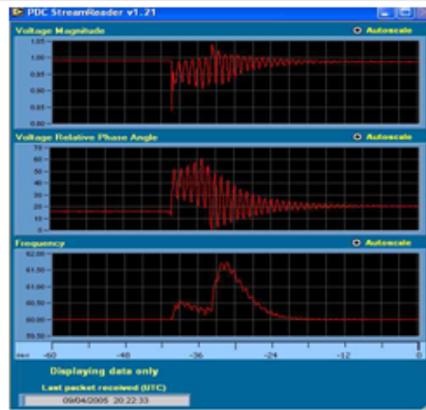
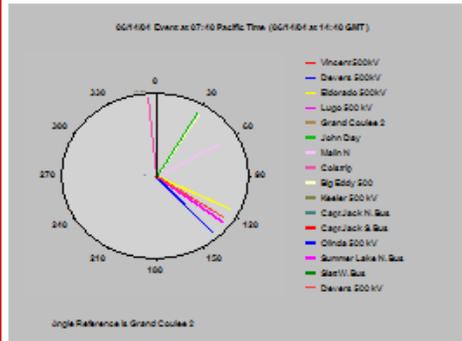


First PMU



Analog Displays

**Now**



**2014**

Standard feature (relays, DFR, controllers, equipment monitors)

On major interconnections

Some distribution PMUs

Improved communication & infrastructure, including control

Standard SW tools included in EMS/SCADA

Interoperability standards deployed

**2018**

Thousands of PMUs world-wide

Higher data rates

Fully in Distribution

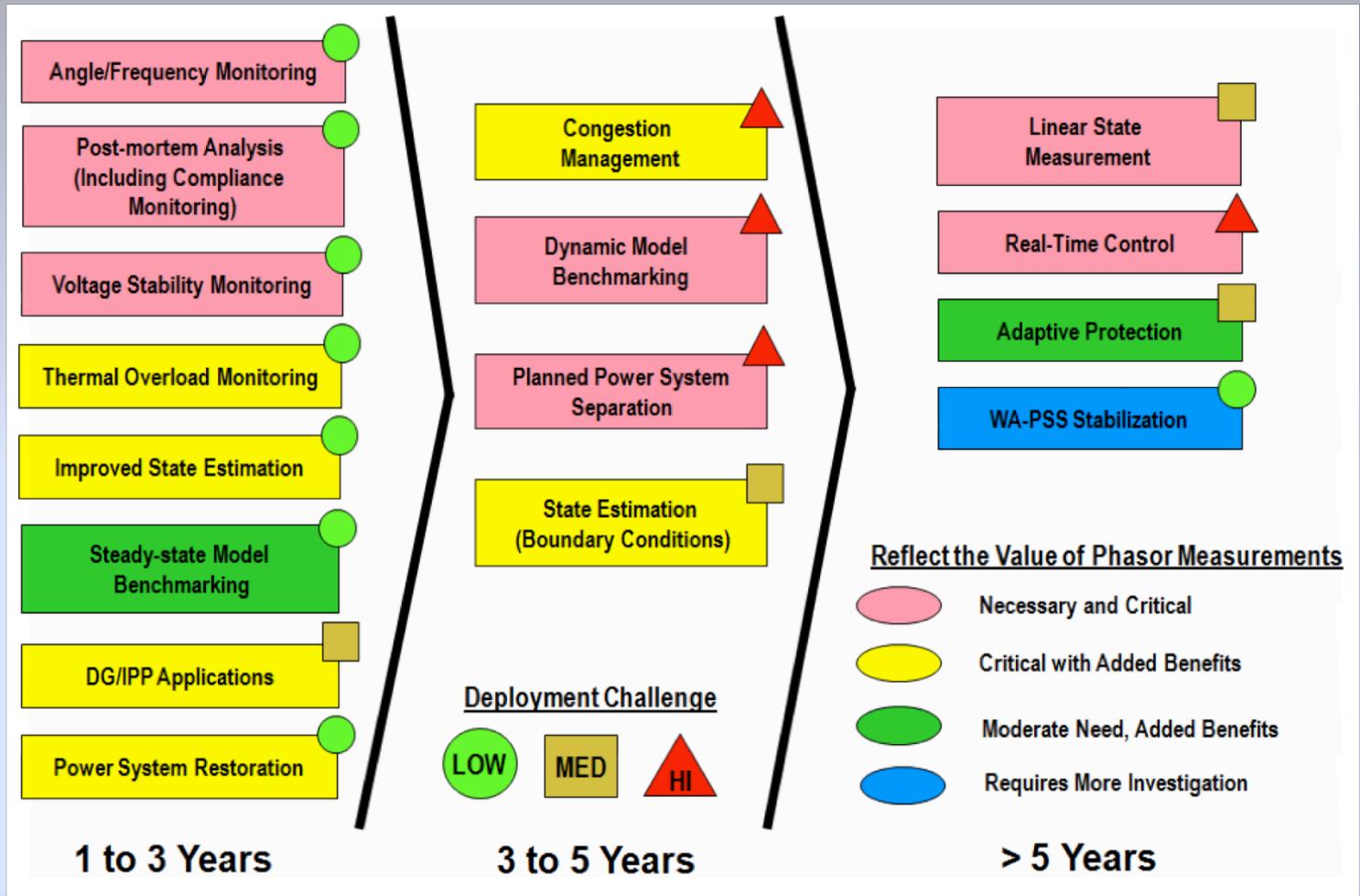
Fast Adaptive Protection

Integrated in standard business and operational practices

Distributed comm. architecture, fully-integrated with EMS/SCADA

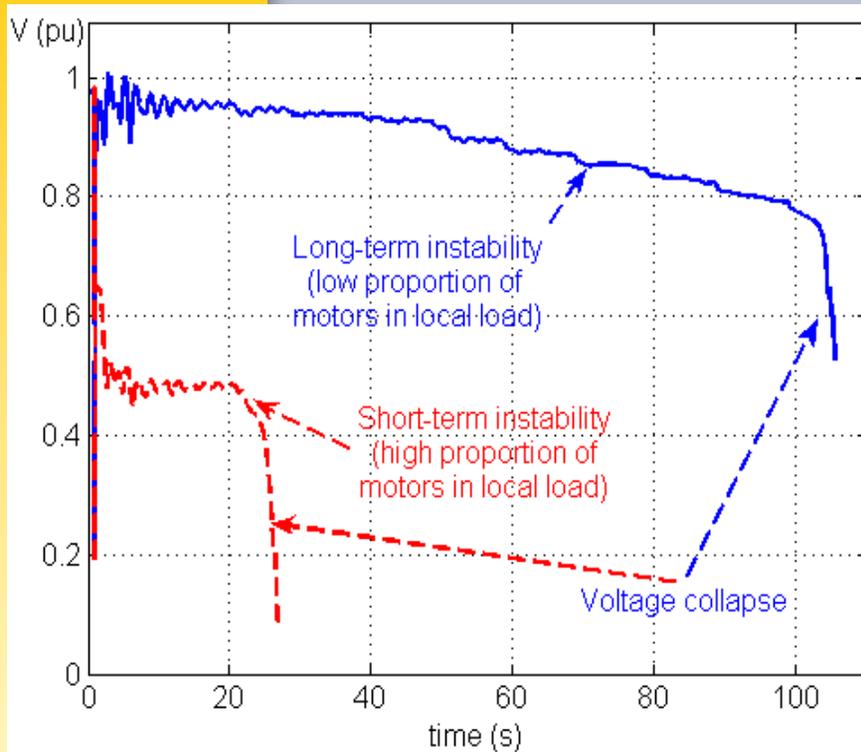


# NASPI/DOE/PIER Roadmap

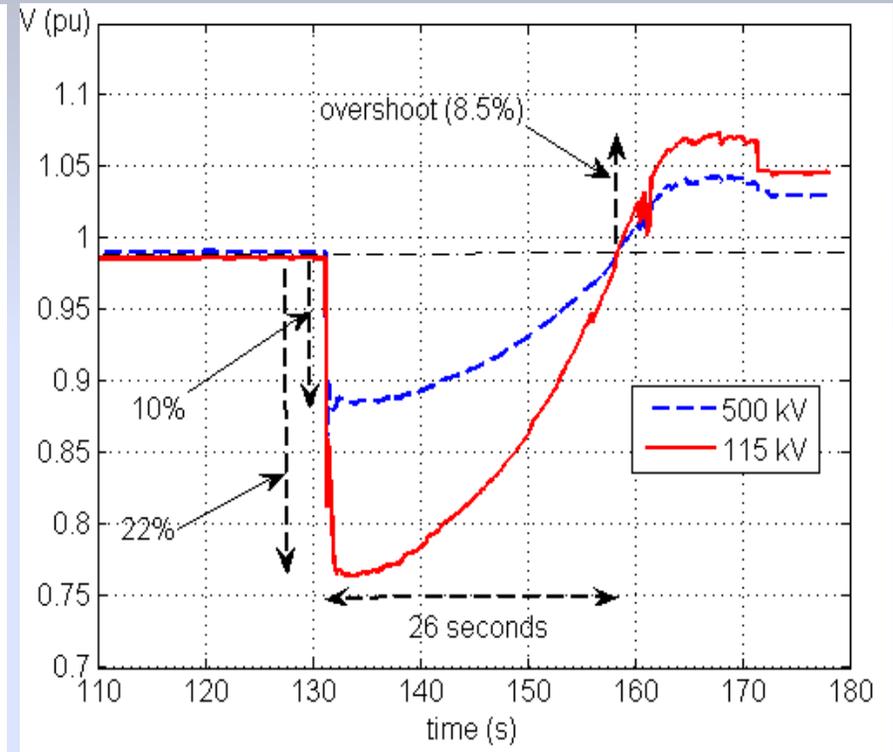


# Voltage Related Issues

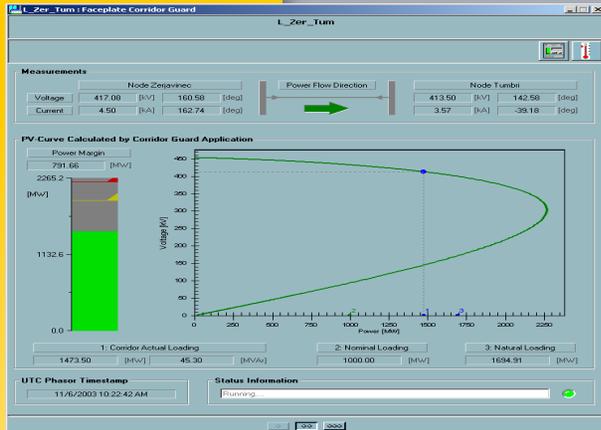
## Voltage Instability: Short- and Long- Term



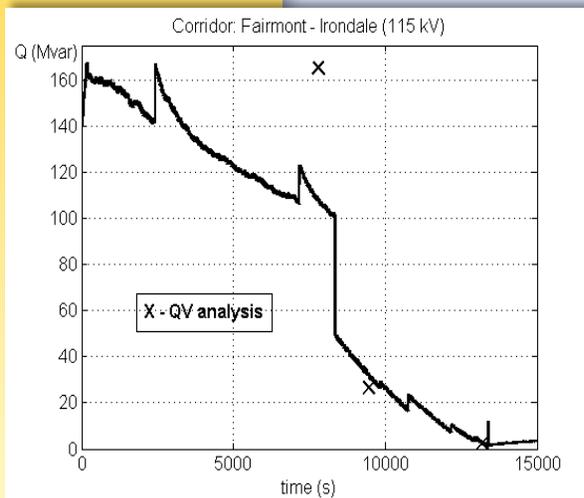
## Fault Induced Delayed Voltage Recovery (FIDVR)



# Voltage Stability Assessment



Source: ABB



Source: BPA



## Model-based simulation tools:

- Voltage Stability Assessment (VSA) based on State Estimation contingency analysis
- Tracking the relative distance from voltage instability continually in real-time
  - Distance to the nose of the PV curve
  - State Estimation based stability boundary
- Sensitive to model accuracy and dynamic system changes

## Measurement-based indicators:

- Monitor available reactive power levels (capacitor/reactor reserves, tap-changers)
- Singular Value Decomposition (SVD)/Sensitivity
- Distance of the load's apparent impedance to the Thevenin impedance – Real-time voltage instability prediction (VIP, REI, VIP Improved/RVII)