Synchrophasors and the Smart Grid

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Book Outline

- Introduction
  - -Definitions -Motivation -History -State-of-the-art
- Technology Background
  - -Standalone PMUs -PMU-enabled IEDs -PDCs
  - -System Architecture and Visualization
- Time Synchronization
  - -GPS Receivers -Local Time Synchronization
  - -Time Synchronization over a Communication Network
- Communications
- Stability Monitoring
  - -Requirements -New Algorithms -Implementation
- Stability Assessment and Control Applications
- Protection and Fault Analysis
- Energy Management Systems
- Development Issues
- Conclusion

Overview

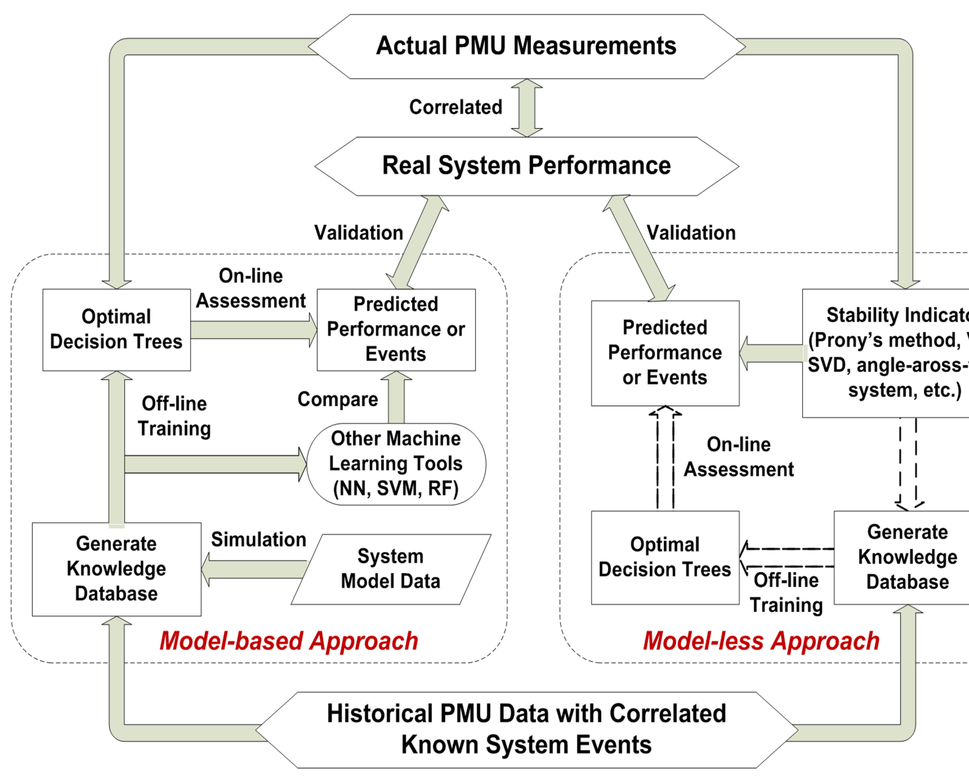
The need for more elaborate instructional material is felt throughout the industry as the fundamental issues are being encountered and explored. This effort includes:

- Develop comprehensive educational package;
- Write a text book and prepare a set of presentations.

The presented research is an extension of two chapters of the book:

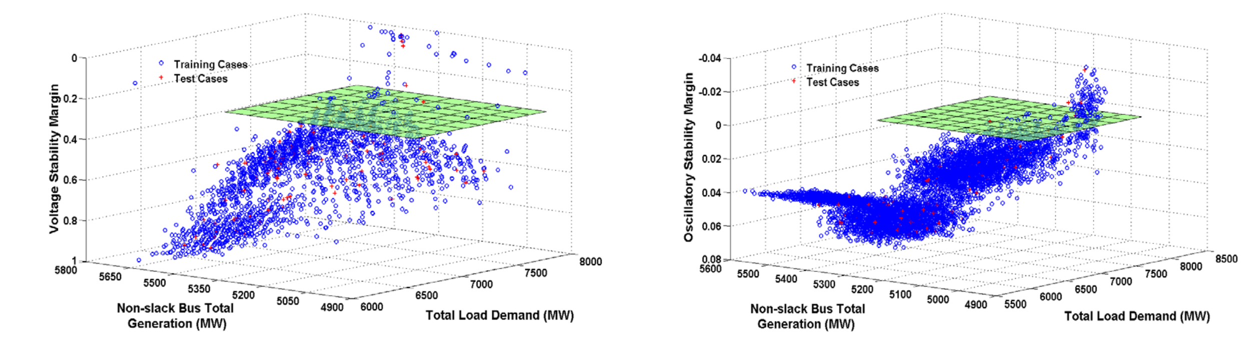
- Data mining to characterize signatures of impending system events;
- Examine the efficacy of CART;
- Model-based and model-less methods;
- Validate using actual PMU data.

The actual PMU measurements are provided by Entergy, SRP and AEP.



Research Status

♦Knowledge Base



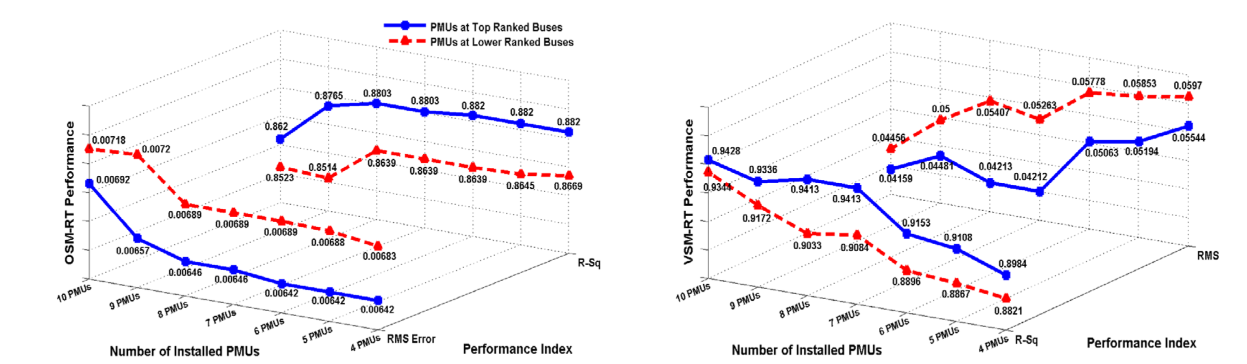
♦Robustness Test

- Robustness in case of measurement error
- Capability to accommodate topological variation

♦*Combined Bus Ranking* for Optimal PMU placement

- Derived from DT *Variable Importance*:

$$CBR_i = \sum_{v \in V} VI_{OSM}(v, i \in v) + \sum_{v \in V} VI_{VSM}(v, i \in v)$$



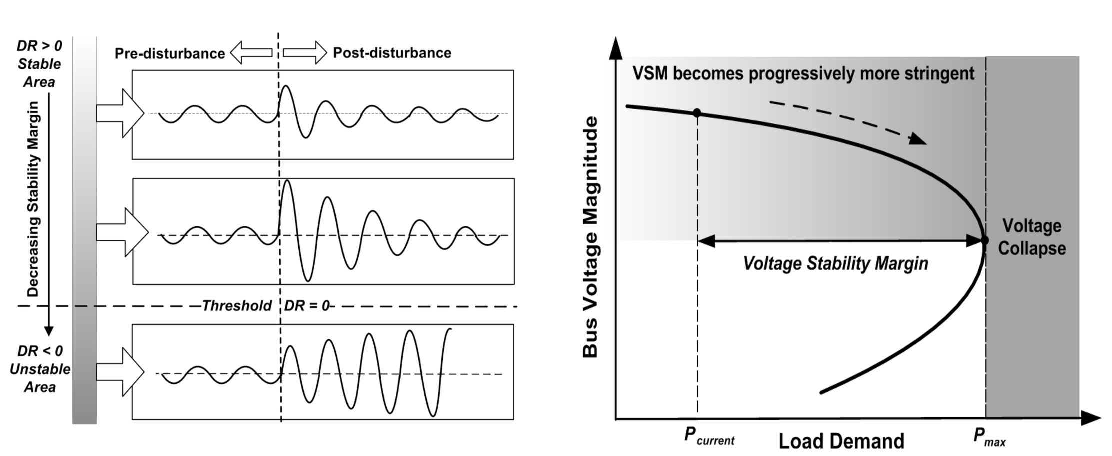
On-line Stability Monitoring

♦ Advantages of Decision Tree (DT):

- Computationally less involved;
- Fast and accurate if well trained.

♦Target system performance:

- Oscillatory stability - Voltage Stability



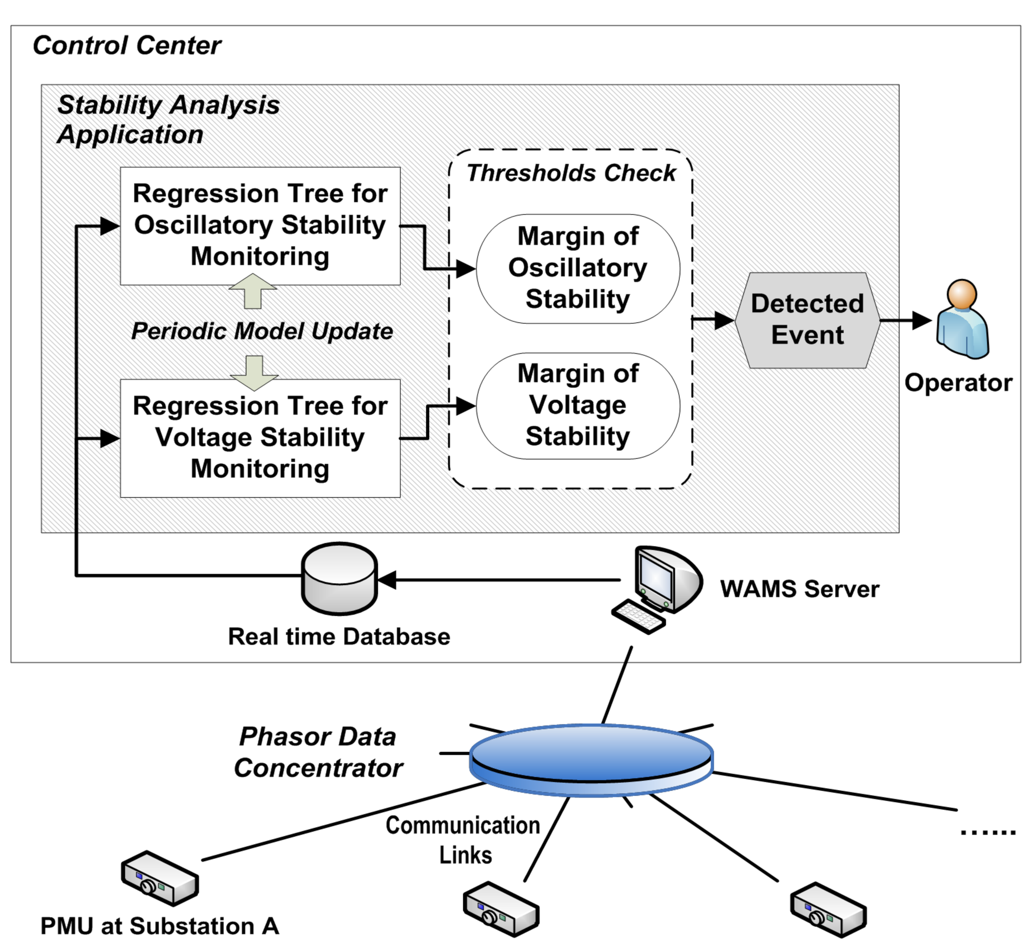
♦ Stability indicators:

- Critical damping ratio and CPF-based margin

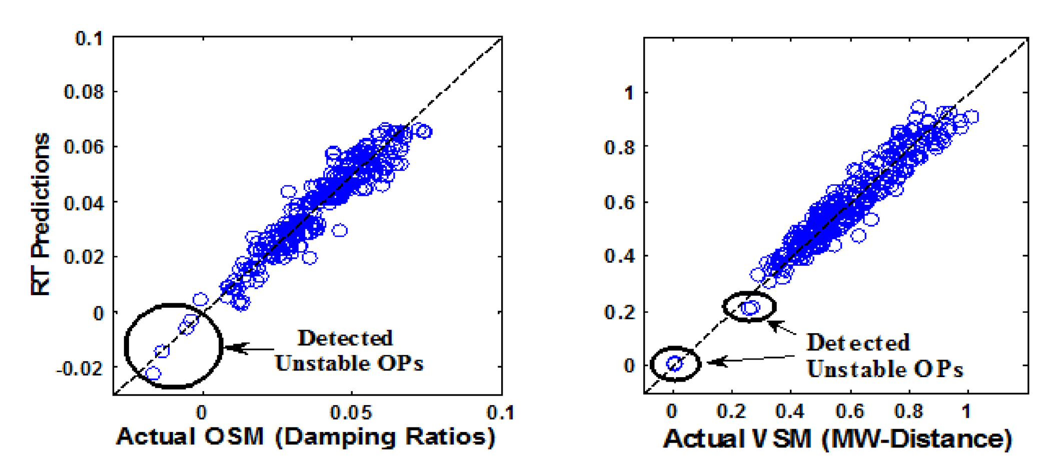
♦ Issues being investigated:

- Predict stability margin using regression tree;
- Compare the performance of DT with Neural Network, SVM, Random Forest, and Fuzzy_DT;
- Test the robustness of DT;
- Model-less approach.

Proposed Framework



- Time-aligned by PDC. Deliver to control center;
- Drop OP down the tree to obtain stability margin.



Model-based Approach

♦Knowledge Base Generation for DT:

PSEUDO-CODE FOR KNOWLEDGE BASE GENERATION

1. Initialize PSS/E in Python
2. Import system model parameters (*.raw)
3. No. of Generation Buses = m, No. of Load Buses = n
4. Derive the vector of base case active power generation
5. Let u (u∈N) be the iteration count. Change $C_{G,L}\%$ each step
   Suppose G_1 is slack bus. Repeat:
   for $A_2=0 \rightarrow u_2$ do
   Scale the output of G_2 to: $P_{G2} = P_{G2}(1 - A_2 \times C_{G2}\%)$
   …
   for $A_m=0 \rightarrow u_m$ do
   Scale the output of G_m to: $P_{Gm} = P_{Gm}(1 - A_m \times C_{Gm}\%)$
   for $A_{m+1}=0 \rightarrow u_{m+1}$ do
   Scale the load 1 to: $P_{L1} = P_{L1}(1 - A_{(m+1)} \times C_{L(m+1)}\%)$
   …
   for $A_{m+n}=0 \rightarrow u_{m+n}$ do
   Scale the load n to: $P_{Ln} = P_{Ln}(1 - A_{(m+n)} \times C_{L(m+n)}\%)$
   Solve load flow at current OP
   If this OP is unsolvable: eliminate
   Oscillatory Stability Analysis:
   Import model dynamic data (*.dyr). Derive *A* matrix (*.lsa)
   Voltage Stability Analysis:
   Derive the voltage collapse point via CPF-based method
   Export computed OP features
   End Loops
6. Repeat: for $i=0 \rightarrow$ number of OPs do
   Modal analysis of *A* matrix: $DR(\zeta_i)$
   Compute voltage stability index: VS^{i}_{margin}
   End Loop

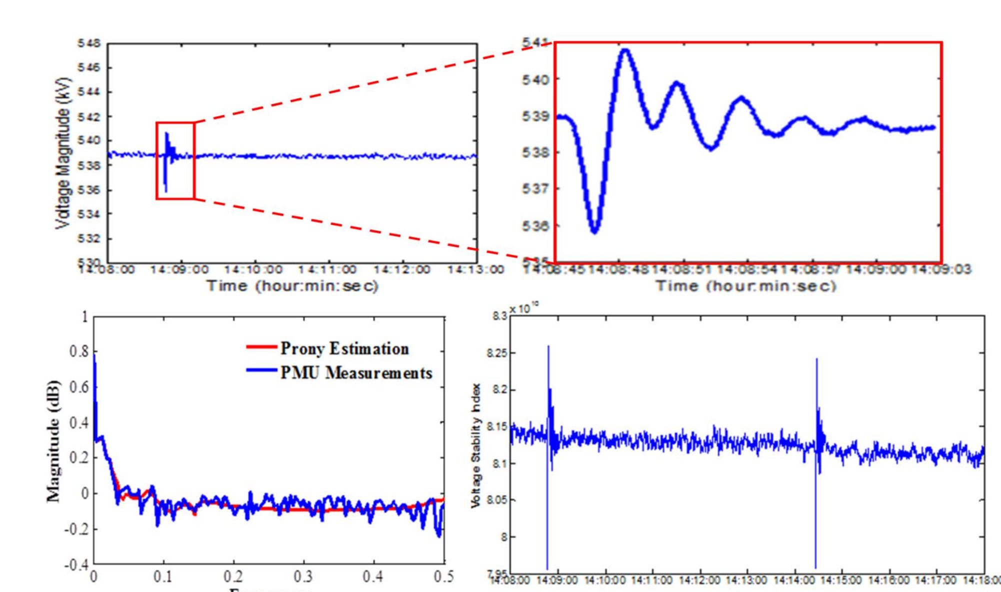
Model-less Approach

♦ Advantage

- Take advantage of limited installed PMUs
- Minimal system model parameters are needed

♦ Potential Metrics

- Damping of critical oscillation mode (Prony's Method)
- Voltage stability index using synchrophasors at line two ends (Zheng and Kezunovic, 2010)
- Thevenin Equivalent (Martinez *et al.*, 2011)
- Singular Value Decomposition (Overbye *et al.*, 2010)



♦ Issues need to be resolved:

- Online track of Thevenin Equivalent: drift and noise
- Set up representative learning set for DT.

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NASPI North American SynchroPhasor Initiative