University of Manitoba

UM iPGL Intelligent Power Grid Laboratory

# A Software Tool for Real-Time Prediction of Potential Transient Instabilities using Synchrophasors

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# Outline

- Introduction
- Transient Stability Status Prediction Algorithm
- PhasorEye Software Tool
- Laboratory-Scale Hardware Setup
- Test Results
- Conclusion

# Introduction

- Transient instability: Loss of synchronism of a generator or group of generators after a severe disturbance.
- A very fast phenomenon - Generators can potentially lose the synchronism within a few seconds after the disturbance.
- If transient instability can be recognized in advance, emergency control actions can be initiated to prevent it or minimize its impact.
- Common practice is to provide controls referred as special protection systems (SPSs),
  - Event based control actions designed through offline system studies
  - Could become complicated as the power system expands
- Alternative is the response based emergency control based on synchrophasor measurements.

# Preceding work

- Rotor Angle Instability Prediction using Post-Disturbance Voltage Trajectories
  - A. D. Rajapakse, F. Gomez, K. Nanayakkara, P. A. Crossley, and V. V. Terzija - IEEE Transactions on Power Systems, Vol. 25-2, May 2010.
  - Fuzzy C-means clustering, template matching & support vector machine classification
- Support Vector Machine-Based Algorithm for Post-Fault Transient Stability Status Prediction using Synchronized Measurements
  - F. R. Gomez, A. D. Rajapakse, U. D. Annakkage, and I. T. Fernando - IEEE Transactions on Power Systems, Vol.26-3, Aug 2011.
  - Support vector machine classification
- Post-Disturbance Transient Stability Status Prediction using Synchrophasor Measurements
  - D. R. Gurusinghe and A. D. Rajapakse - IEEE Transactions on Power Systems, Early Access, 2016.
  - Phase plane of voltage magnitudes

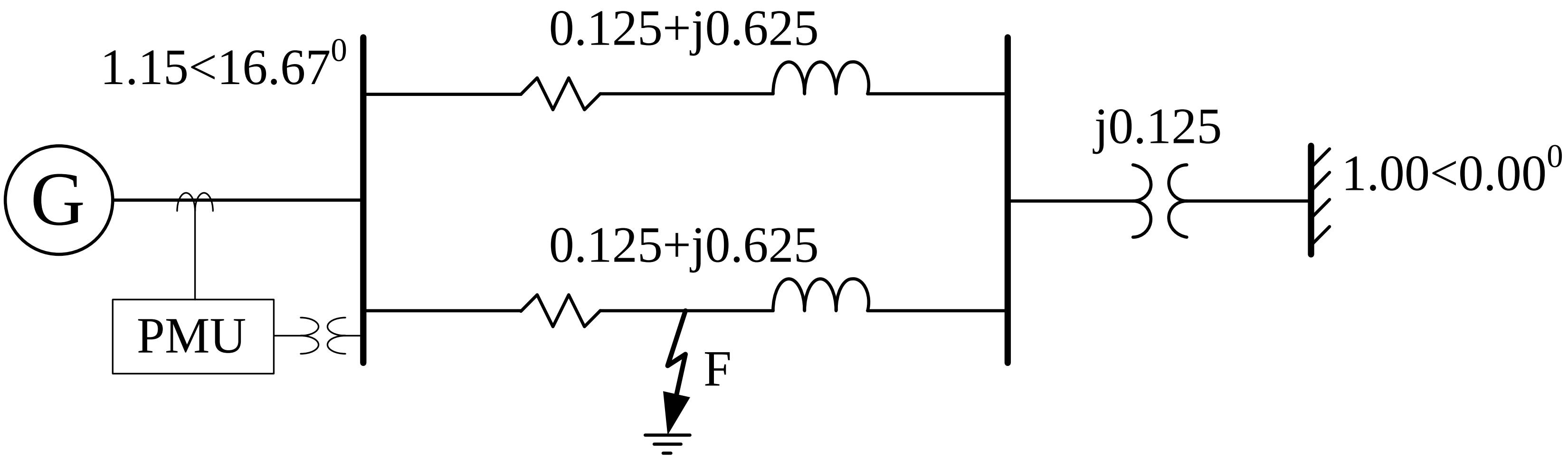
# Objective

**Implement the recently developed transient stability status prediction algorithm [1], [2] in a real-time software tool (PhasorEye) and validate its performance through hardware in the loop simulations.**


[1] D. R. Gurusinghe and A. D. Rajapakse, “Post-disturbance transient stability status prediction using synchrophasor measurements,” *IEEE Transactions on Power Systems* (early access), 2016.

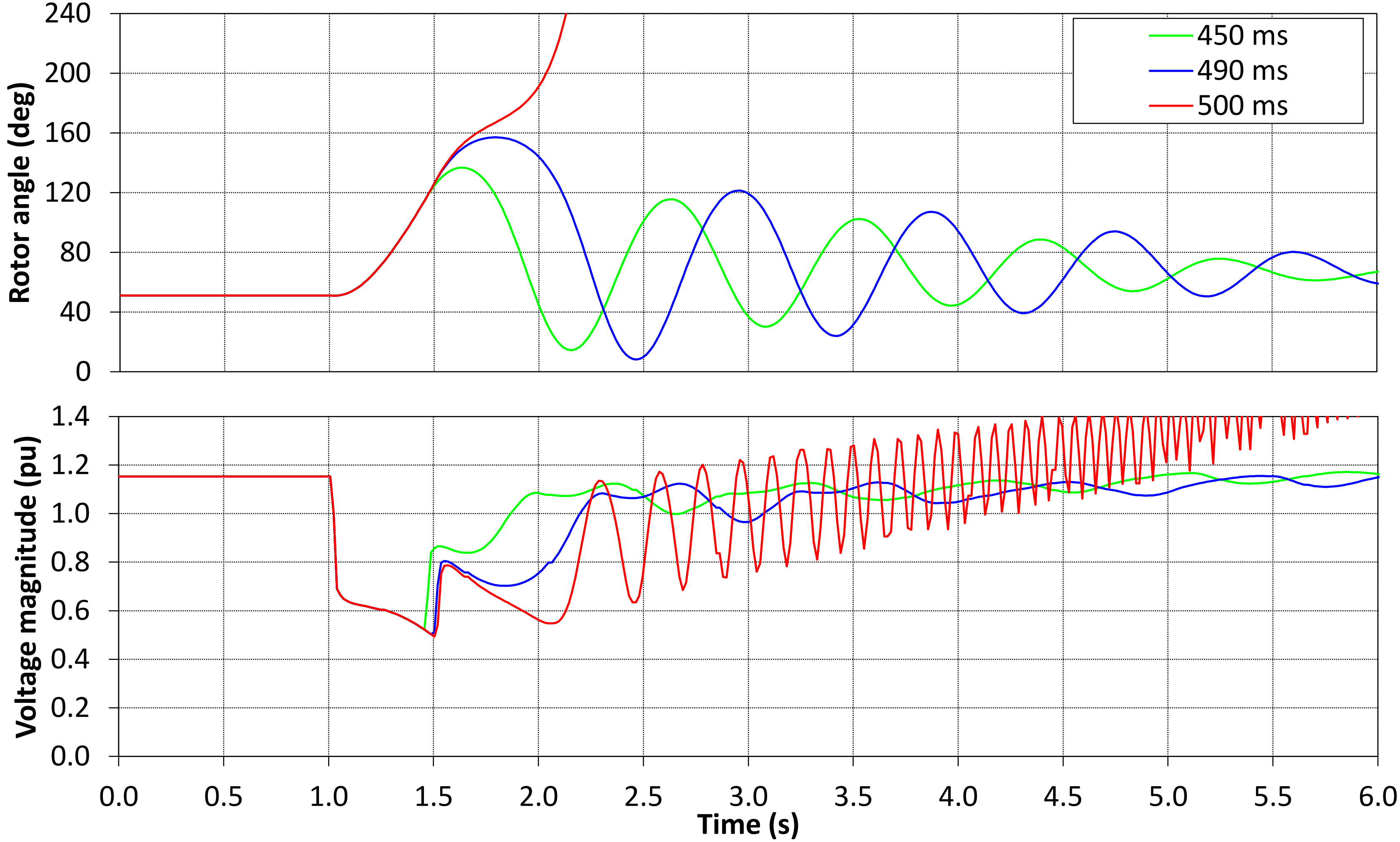
[2] D. R. Gurusinghe, A. D. Rajapakse, D. Ouellette and R. Kuffel, “An application of wide area synchrophasor based transient stability status prediction,” presented at The North American Synchrophasor Initiative (NASPI 2015), San Mateo, CA, USA, Mar. 2015.

# Concept of the Proposed Technique



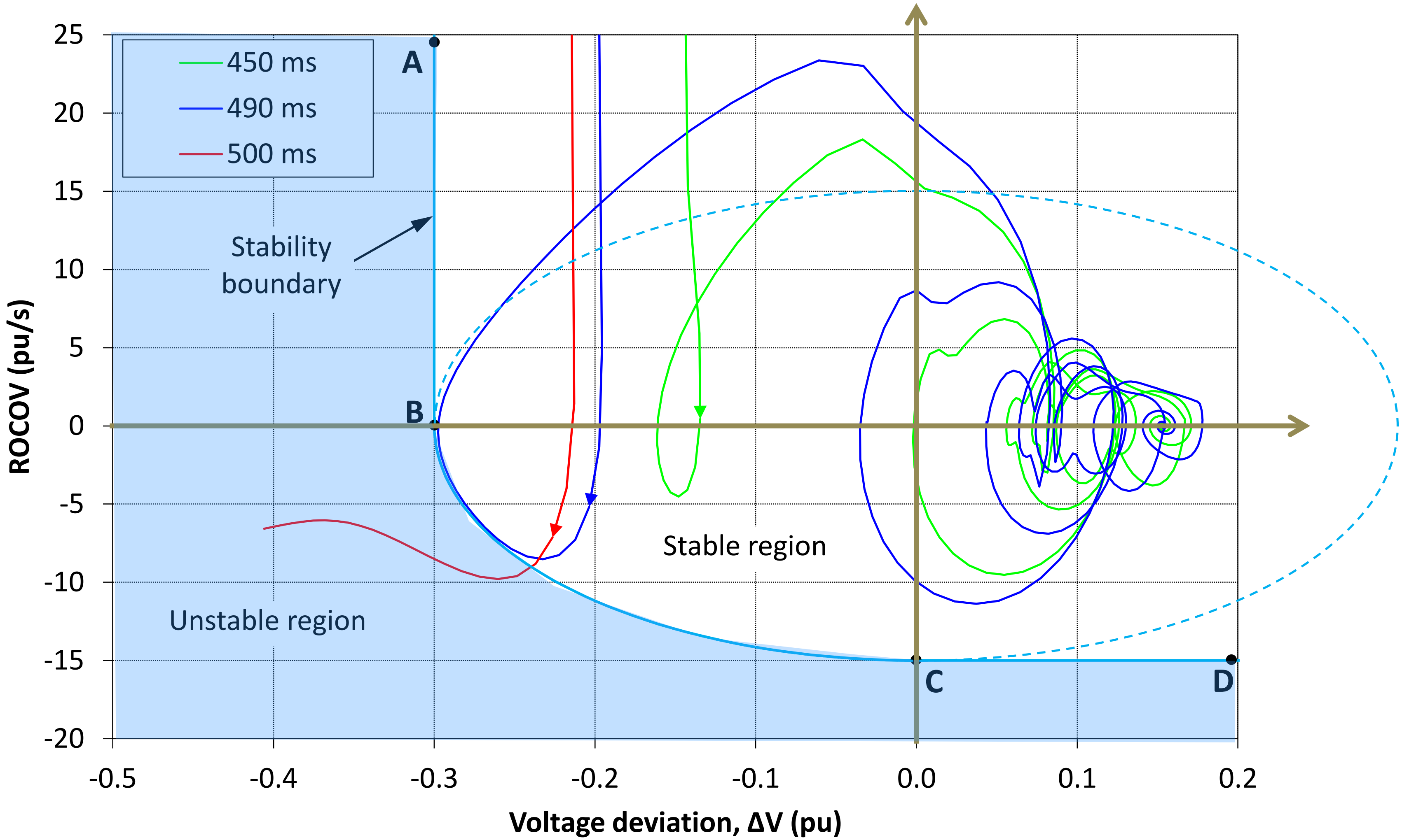

One machine to infinite bus (OMIB) system with the initial steady-state power flow solution

# Concept of the Proposed Technique




Variations of rotor angle and voltage magnitude following a fault

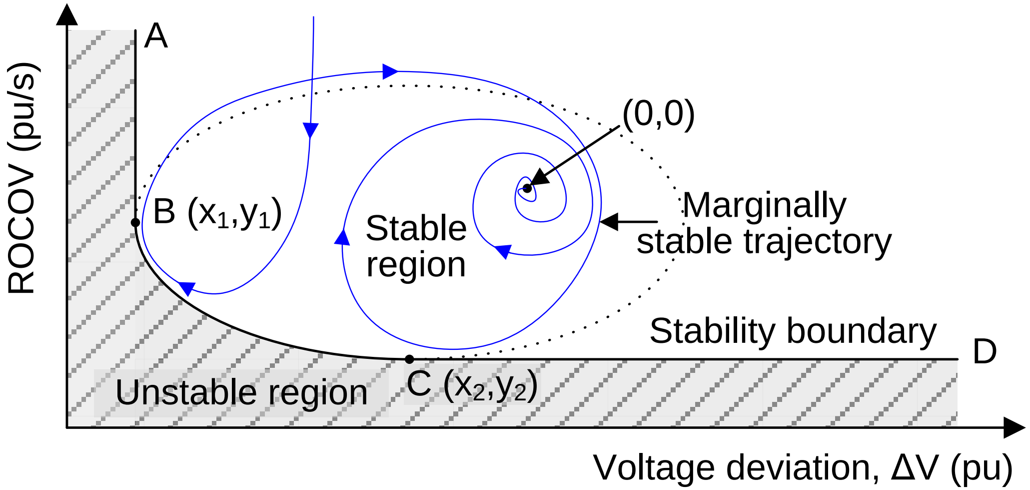
# Concept of the Proposed Method




Plot of ROCOV vs. ΔV following a fault

# Implementation of Algorithm

- **Off-line design**
  1. Identification of contingencies that makes generator marginally unstable through off-line dynamic simulations.
  2. Determination of stability boundary for each generator
- **Real-time operation**
  1. Detection of severe disturbances and triggering the transient stability status prediction algorithm.
  2. Prediction of transient stability status, and trigger emergency control actions

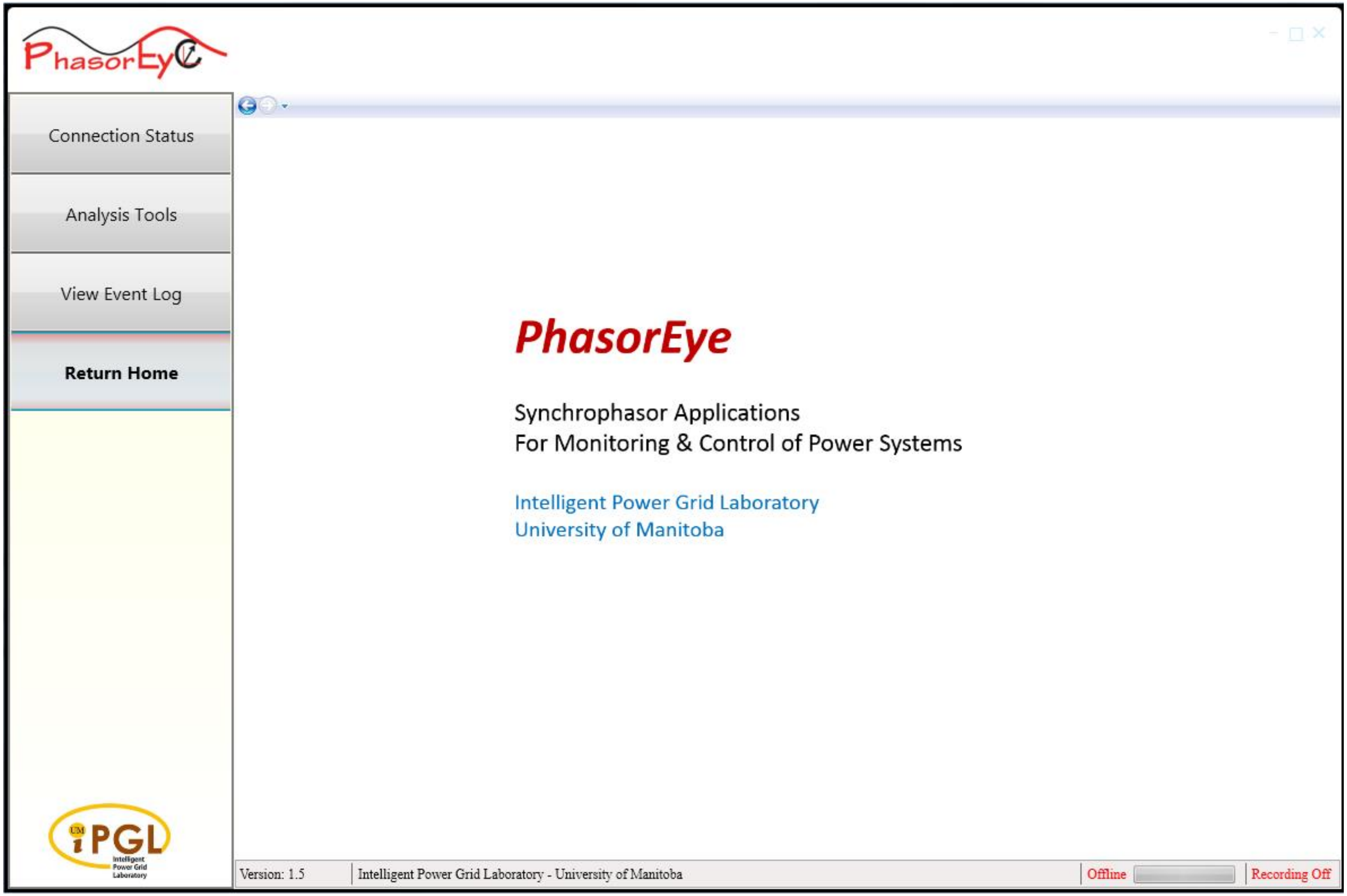


PhasorEye

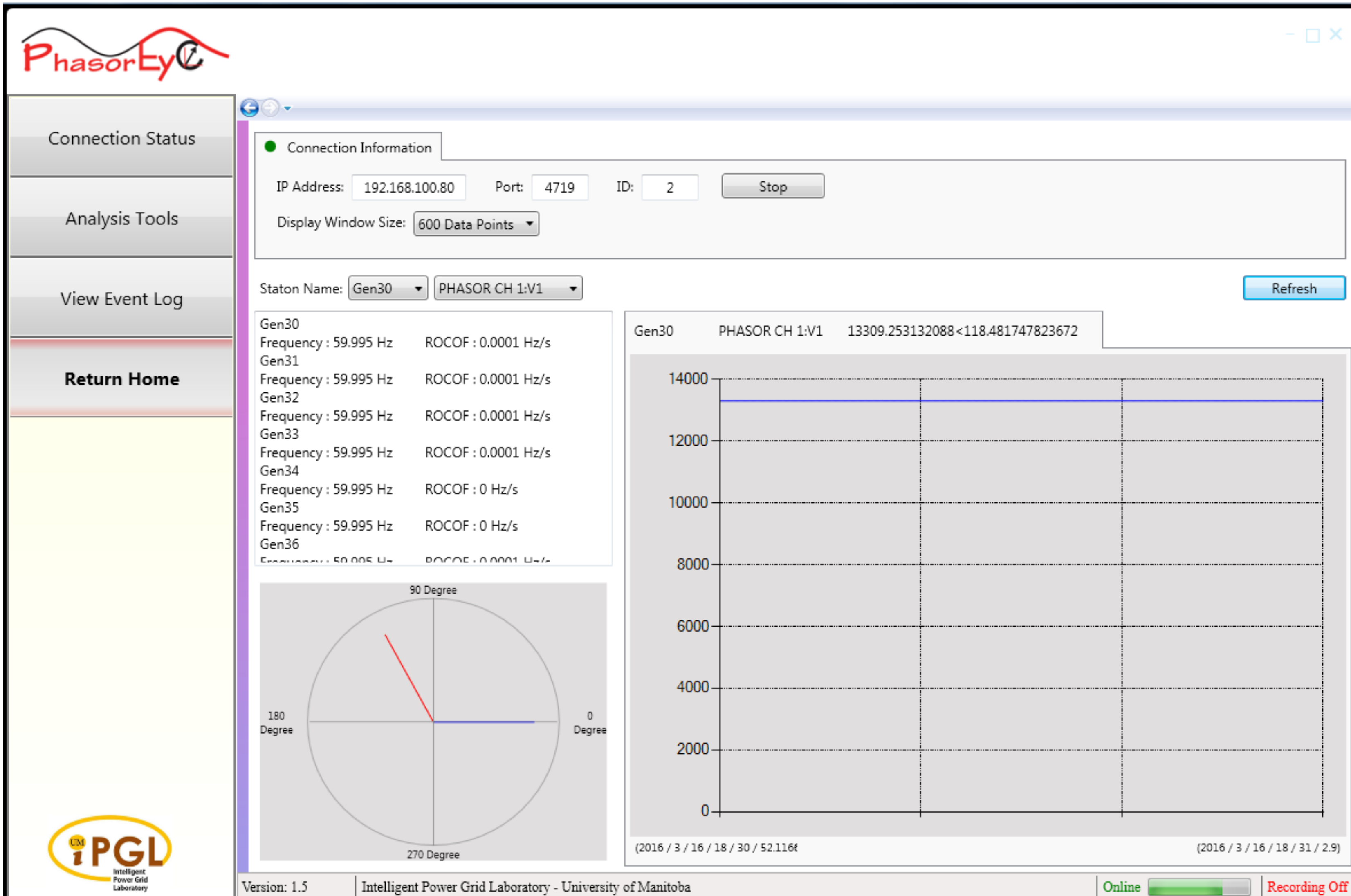
# Software Tool

- Developed at the intelligent Power Grid Laboratory of the University of Manitoba, Canada as a tool for testing synchrophasor applications
  - Implement synchrophasor application programs using an output data stream from a PDC
  - Check the availability of real-time data stream, determine the data configuration and connect.
  - Display/plot selected phasors with geographical information.
  - Record an event log, and save data for a specified duration upon triggered by an event specified by the user.
  - Retrieve and plot recorded data
  - Applications: Transient stability monitoring, line parameter estimation, oscillation monitoring

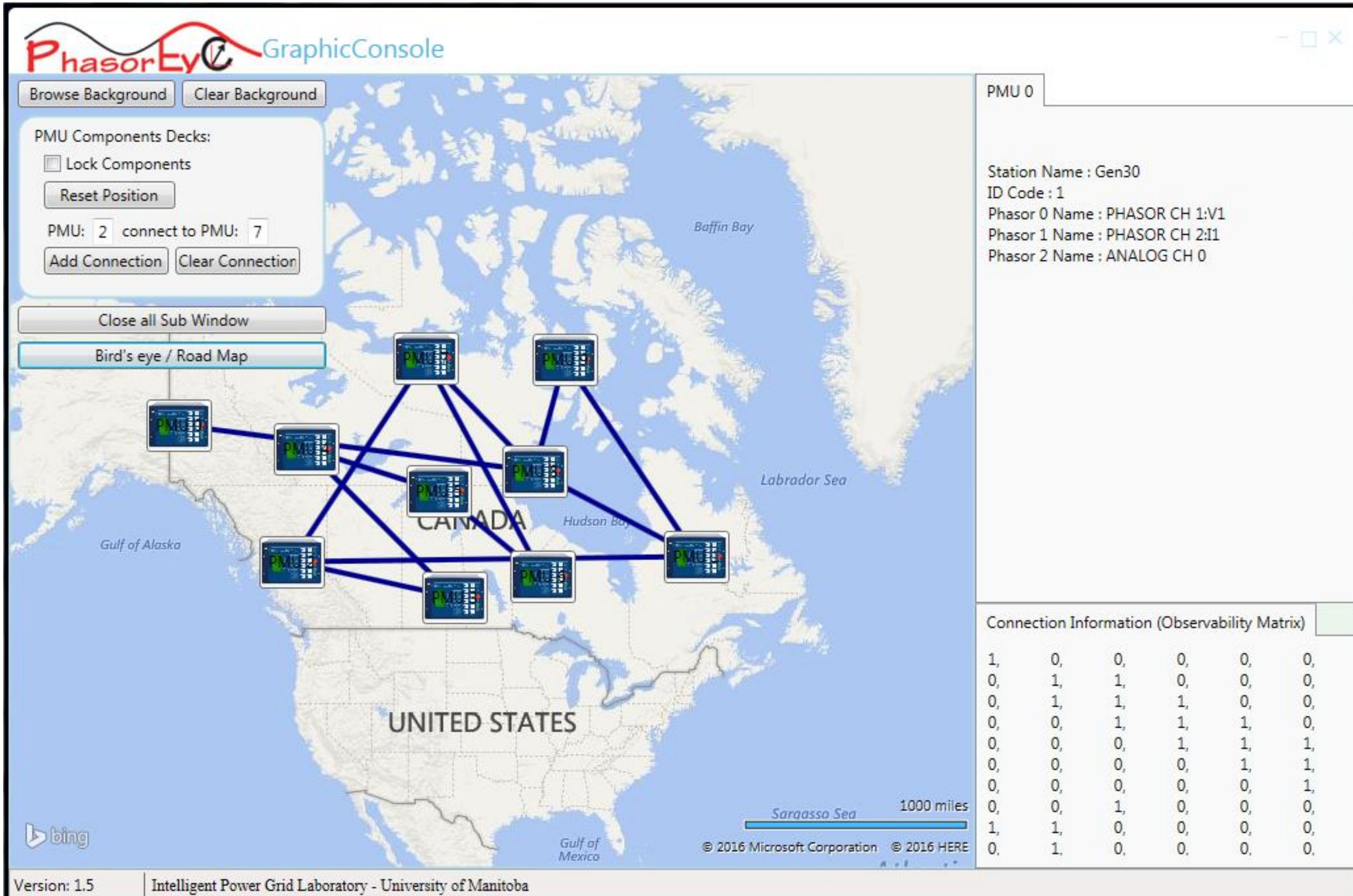
# Features of PhasorEye



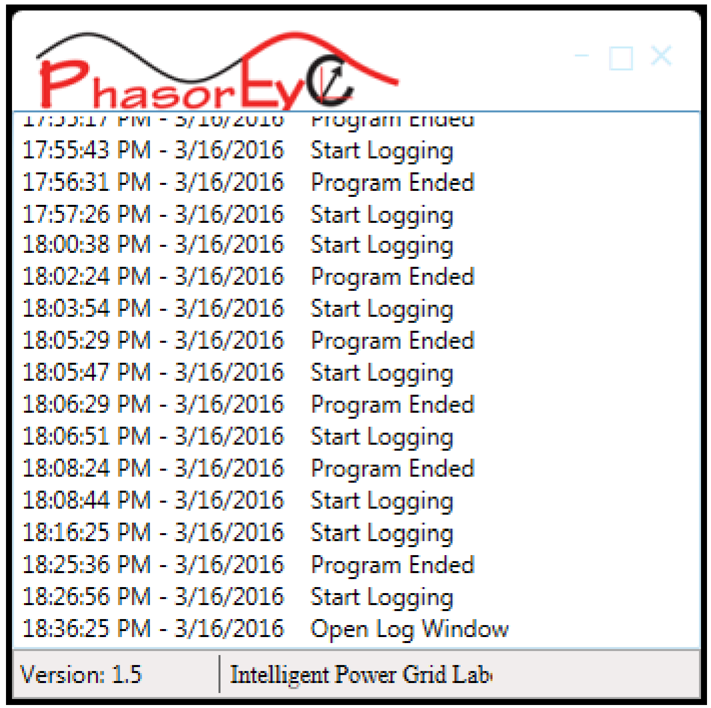
# Features of PhasorEye



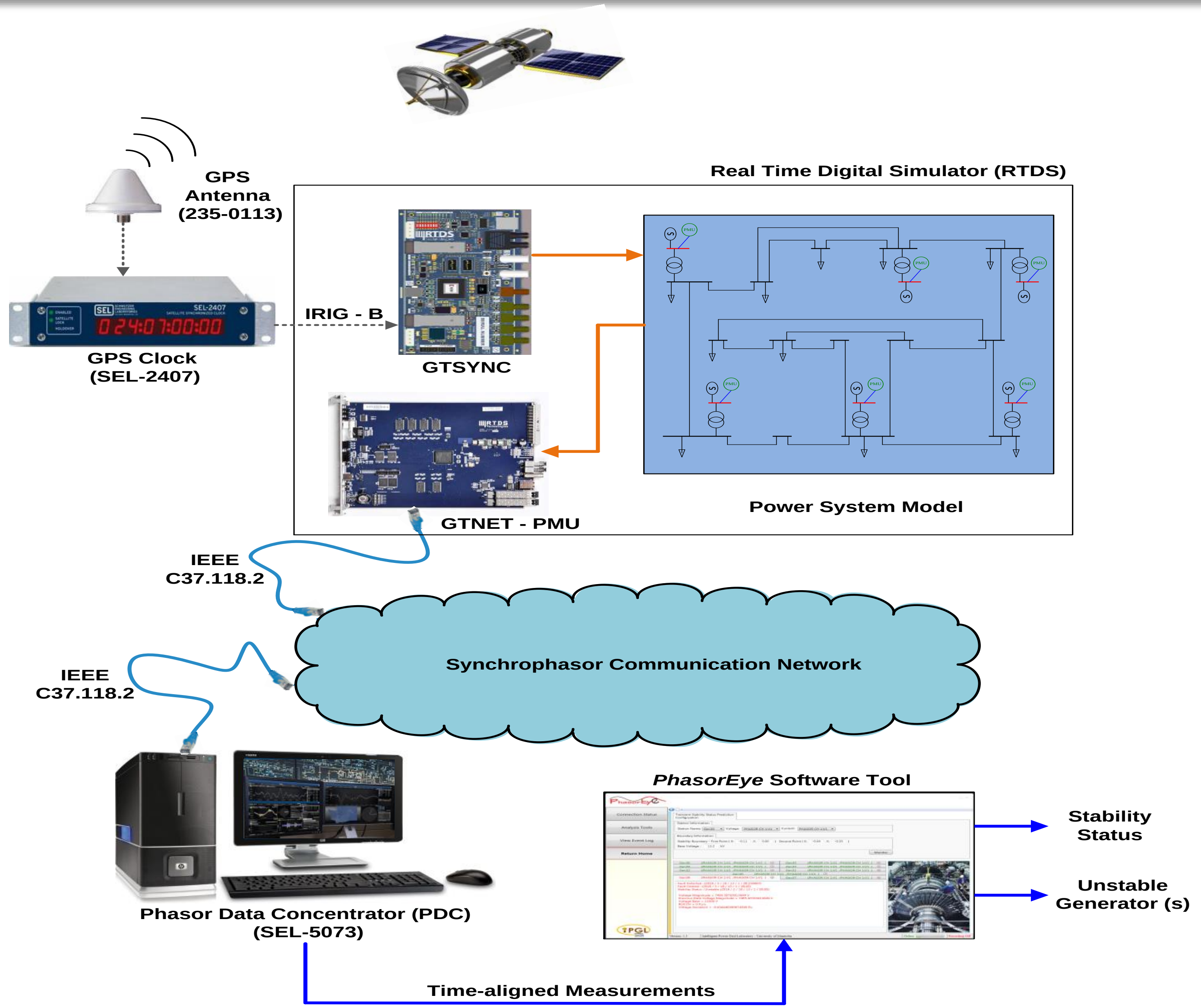
# Features of PhasorEye



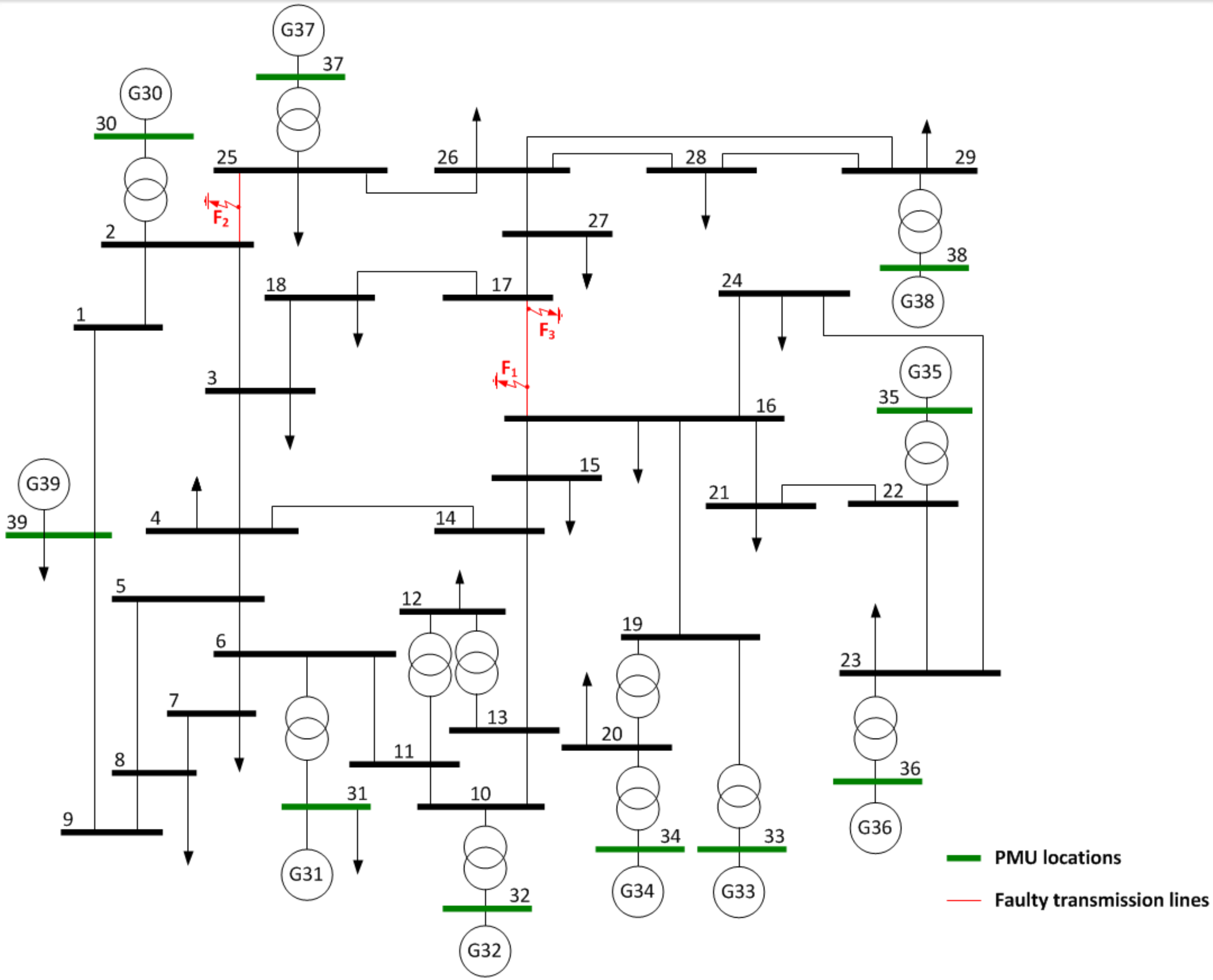
# Features of PhasorEye



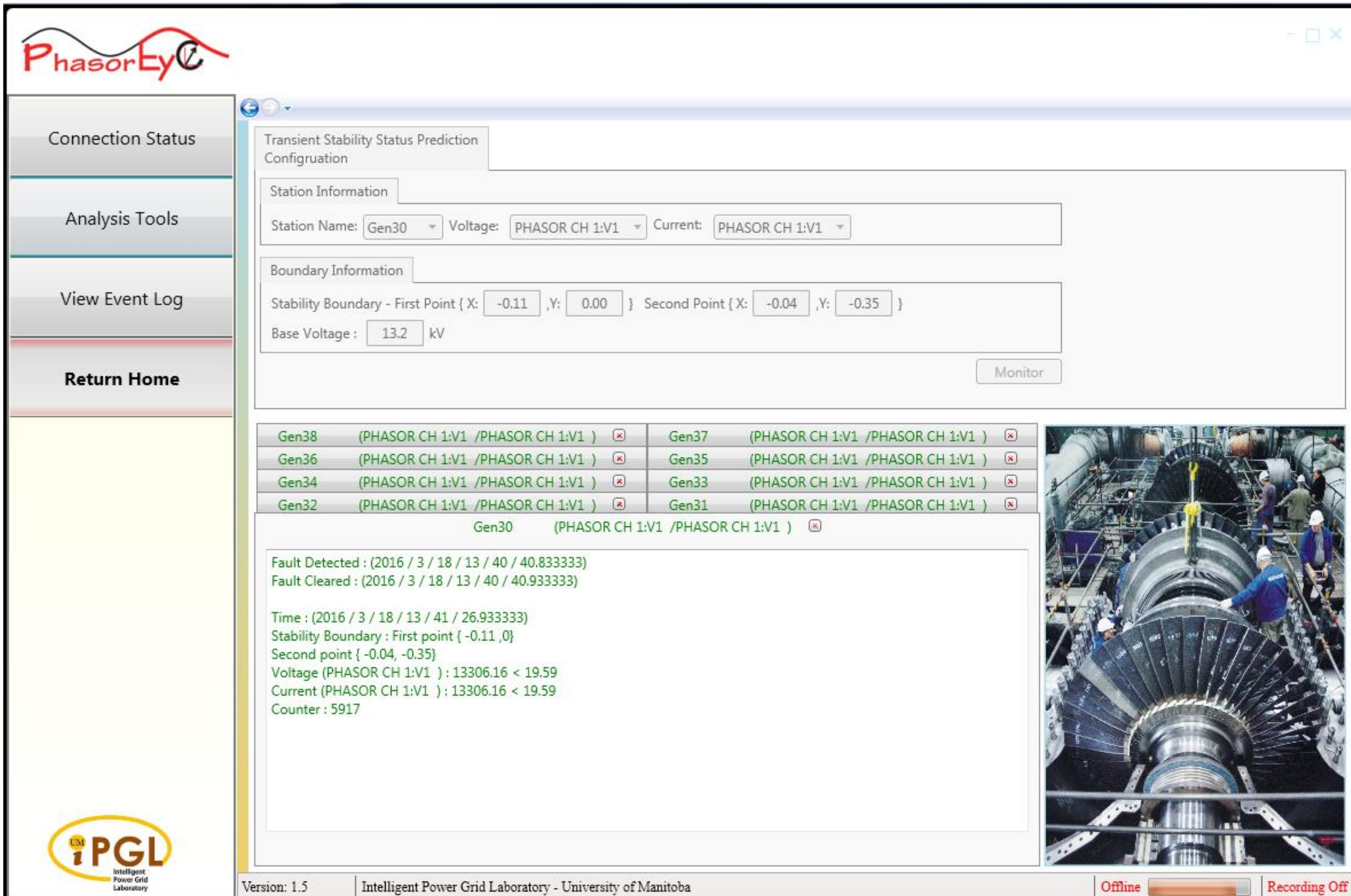
# Laboratory-Scale Hardware Setup



# Simulation Results : IEEE 39-Bus Test System



# Simulation Results : Stable Case



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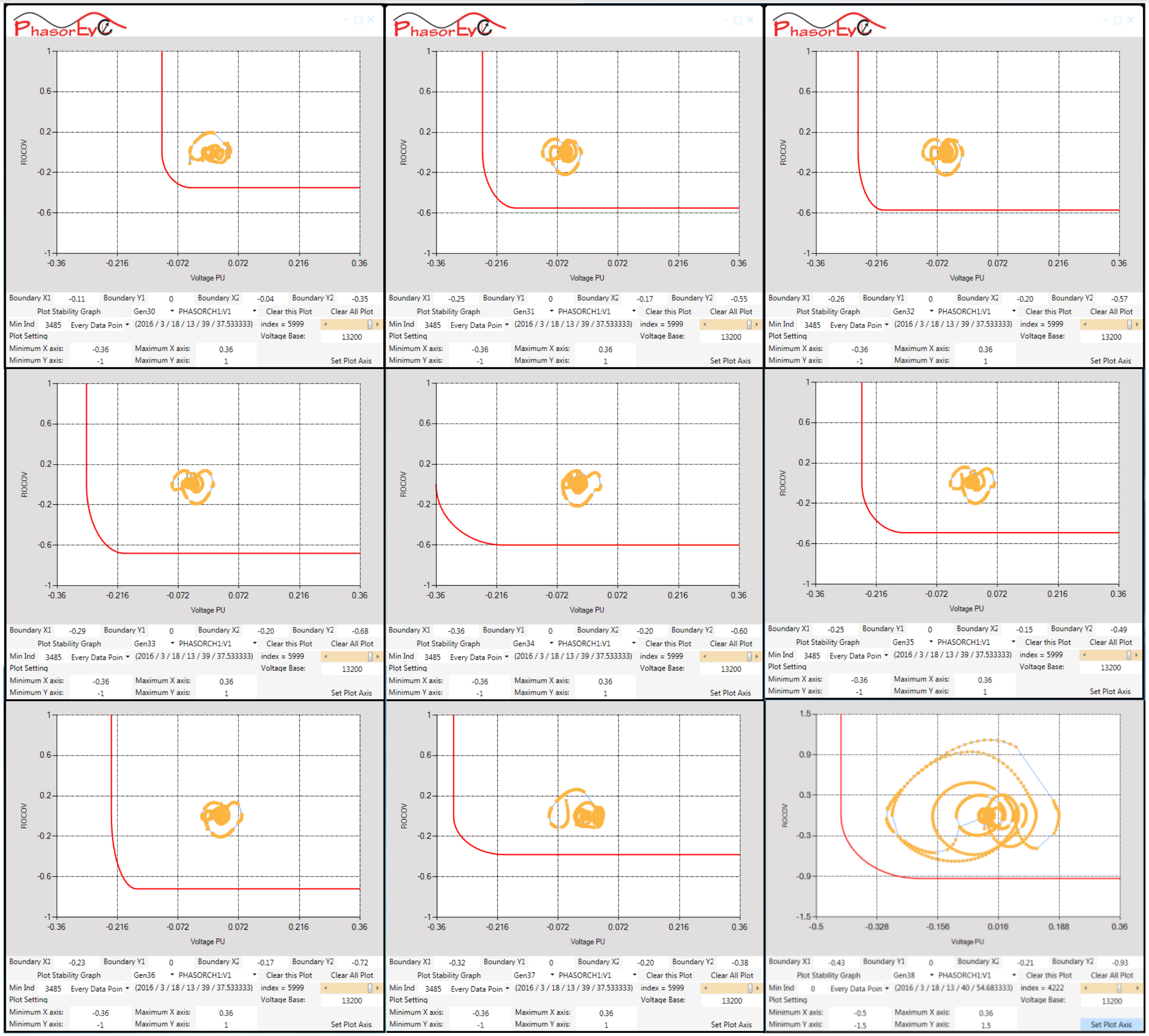
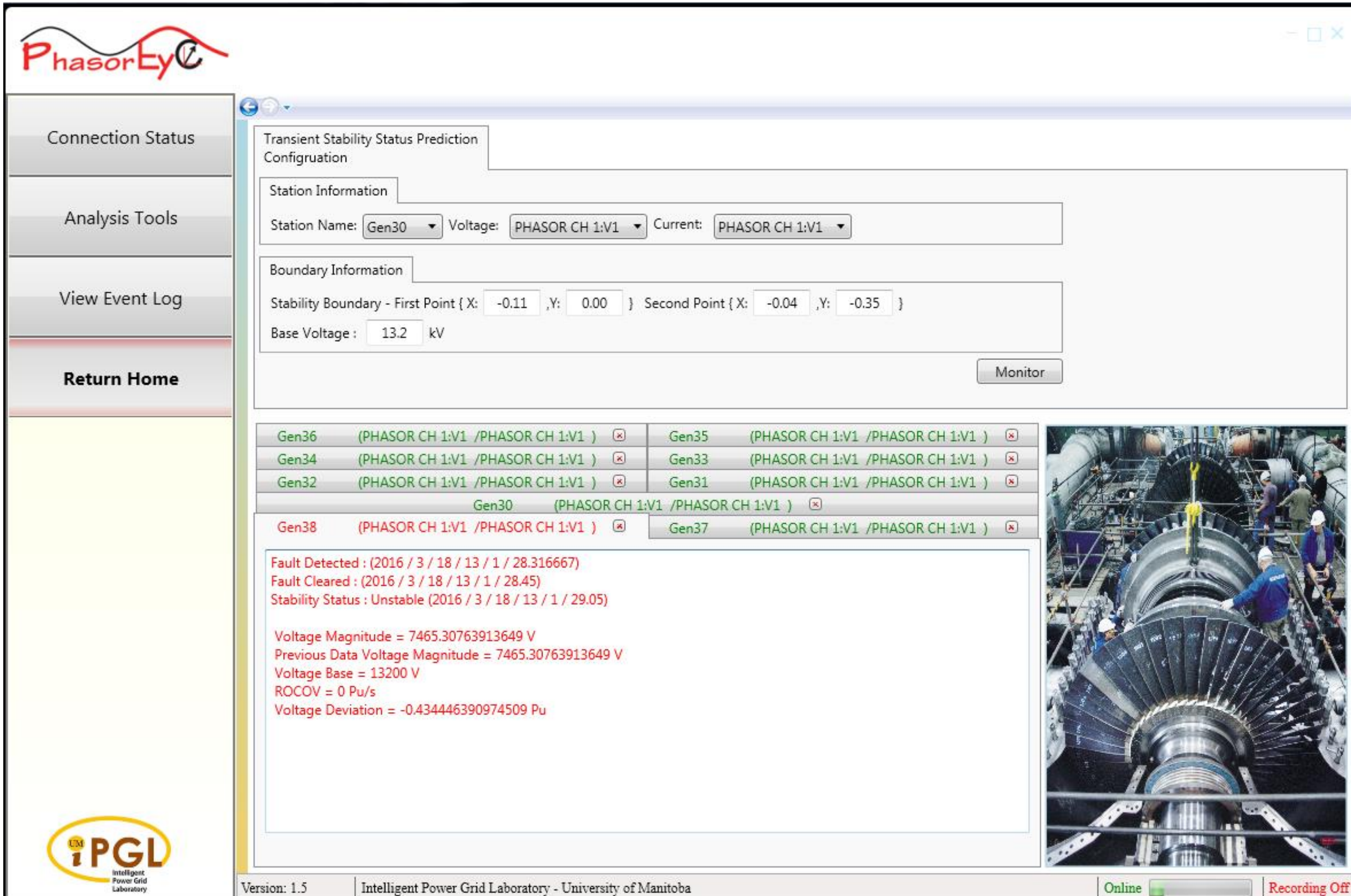
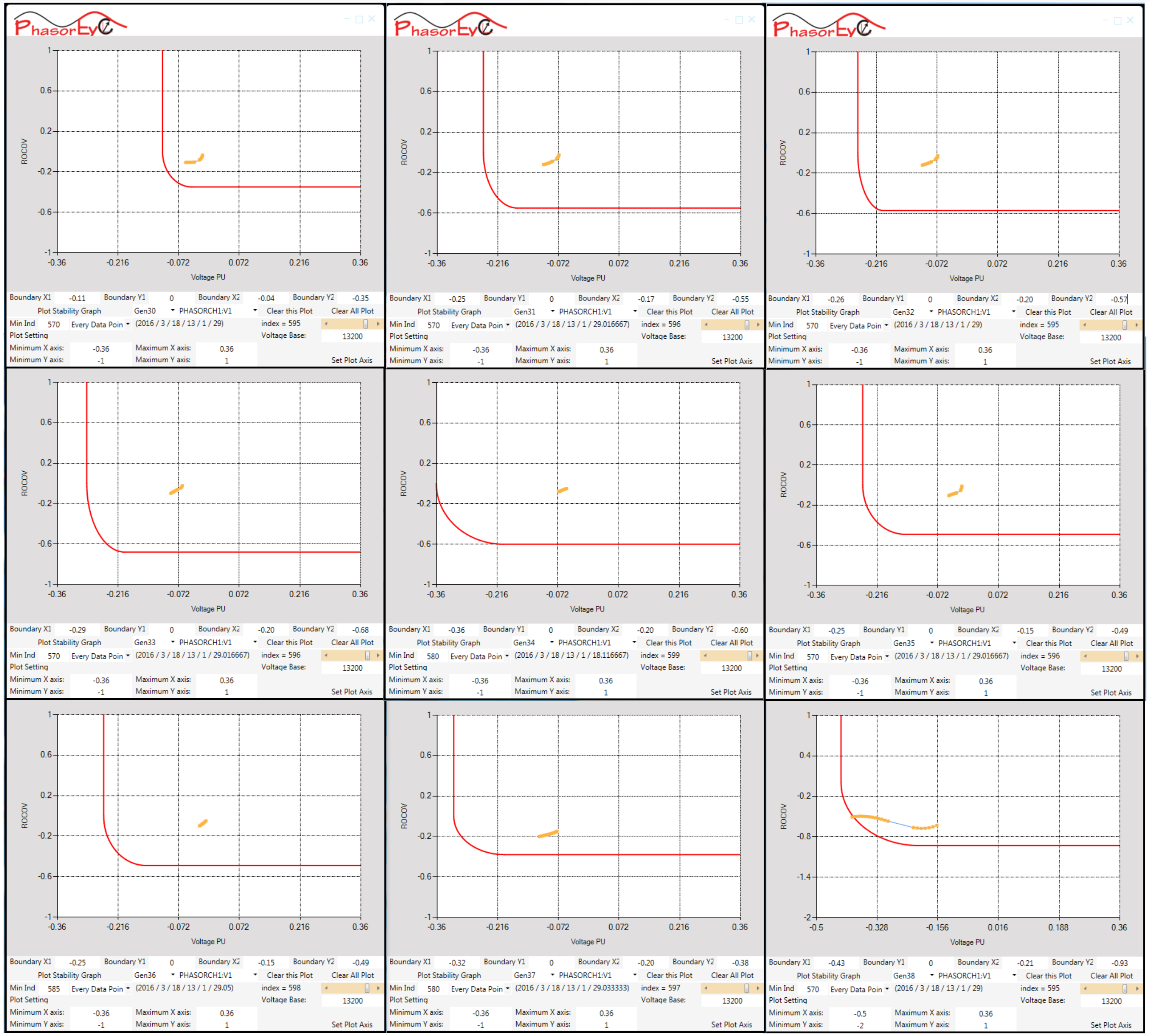


# Simulation Results : Unstable Case



# Simulation Results : Unstable Case



# Conclusion

- A synchrophasor based transient stability status prediction algorithm was implemented in a standalone software tool.
- The effectiveness and practical implementation aspects of the transient stability prediction algorithm was evaluated in a laboratory scale test setup with the RTDS™ simulator.
- We hope to present how the transient stability predictions can be used to initiate emergency control actions in a future NASPI meeting.
  - Load shedding
  - Generator shedding
  - HVDC control

# Thank you

Q & A