UNIVERSITY OF MANITOBA

RTDS Technologies

An Application of Wide Area Synchrophasor based Transient Stability Status Prediction

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Outline

- Introduction
- Concept of the Proposed Method
- Laboratory-Scale Test Setup
- Simulation Results
- Conclusion

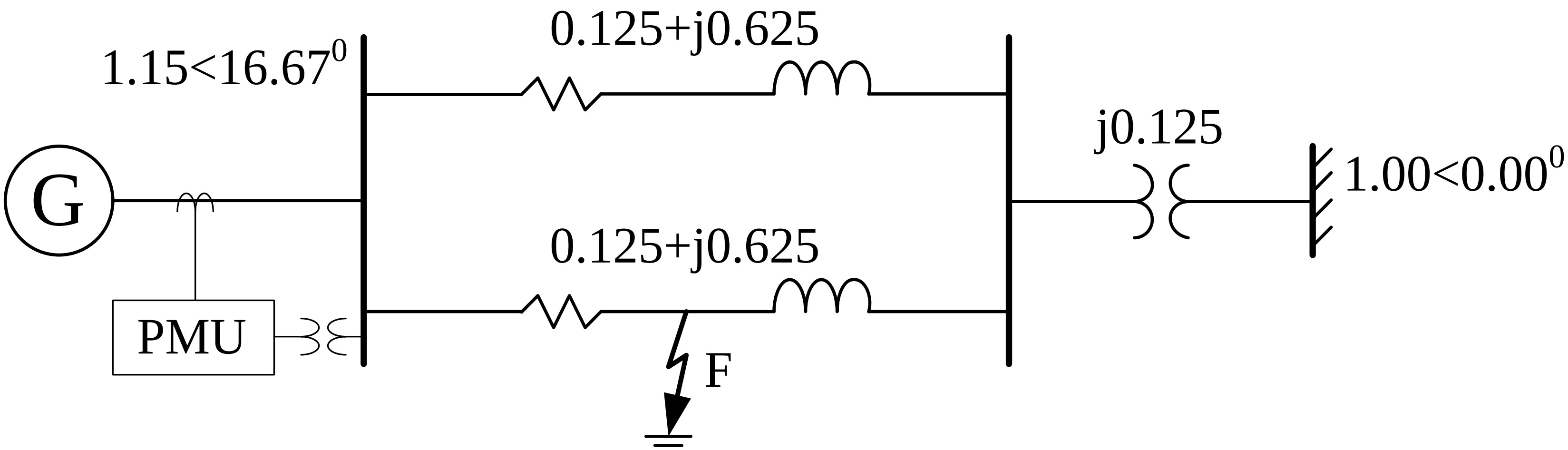
Introduction

- Transient stability is a fast phenomenon and a generator or group of generators can potentially lose the synchronism within a few seconds after a severe disturbance
- Fast recognition of such instabilities provides opportunity to initiate appropriate emergency control actions
- In literature, there are a few basic approaches to predict the transient stability status of a power system:
  - Time-domain simulations
  - Transient-energy-function (TEF) methods
  - Curve-fitting techniques
  - Machine-learning based classification techniques
- However, all of them have inherent limitations and drawbacks

Objectives

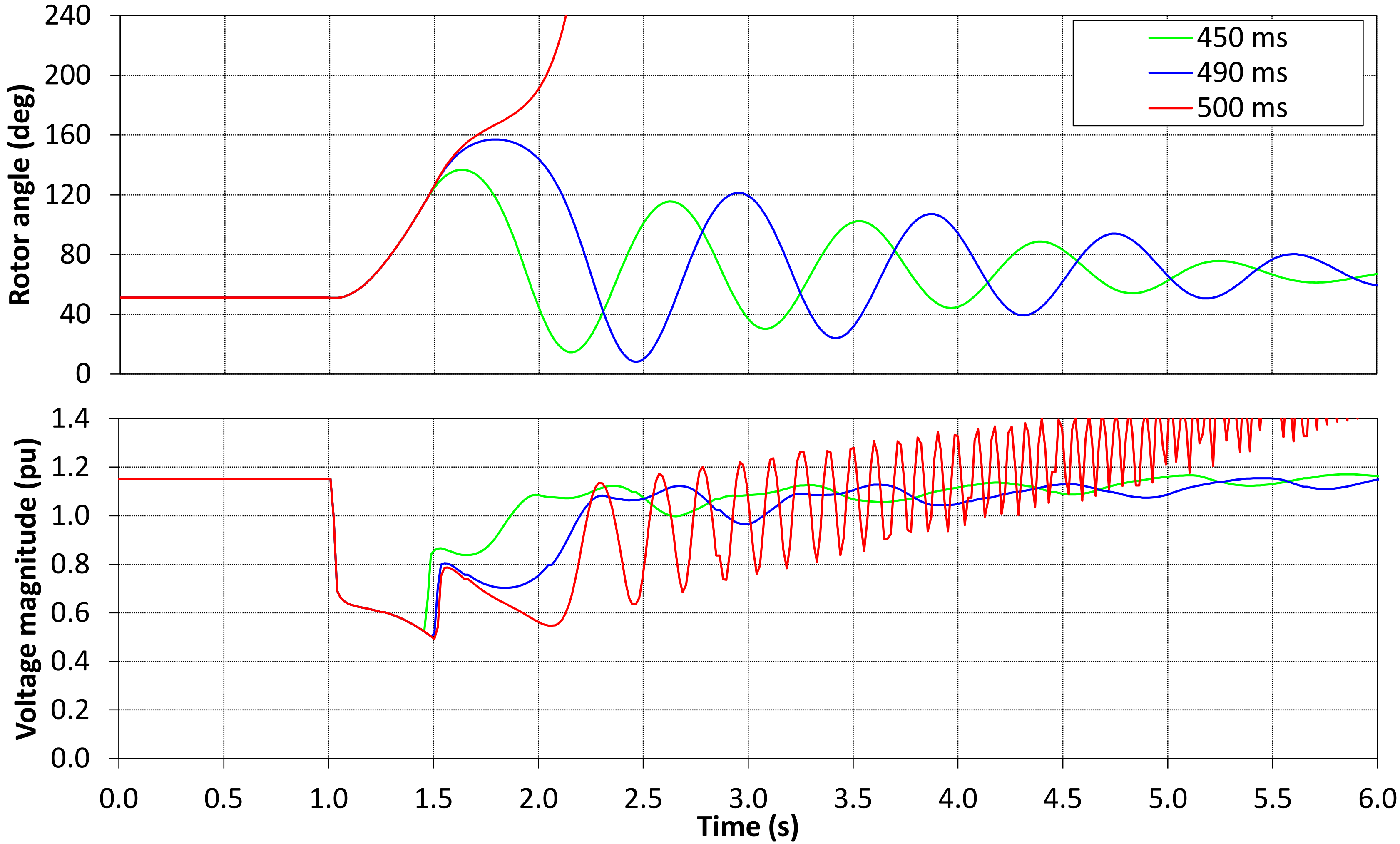
- To develop a method to predict impending transient (rotor angle) instability conditions following a fault
- The proposed new method involves monitoring the loci of generator operating points on ROCOV-ΔV plane with the post-fault voltage measurements obtained from PMUs, and declaring an instability condition if the operating point of any generator crosses a predefined boundary
  - The proposed method is transparent and simple to implement
  - It is capable of predicting first-swing transient instabilities as well as multi-swing transient instabilities
  - The method can recognize the unstable generator(s) enabling the initiation of specific emergency control actions

Concept of the Proposed Method



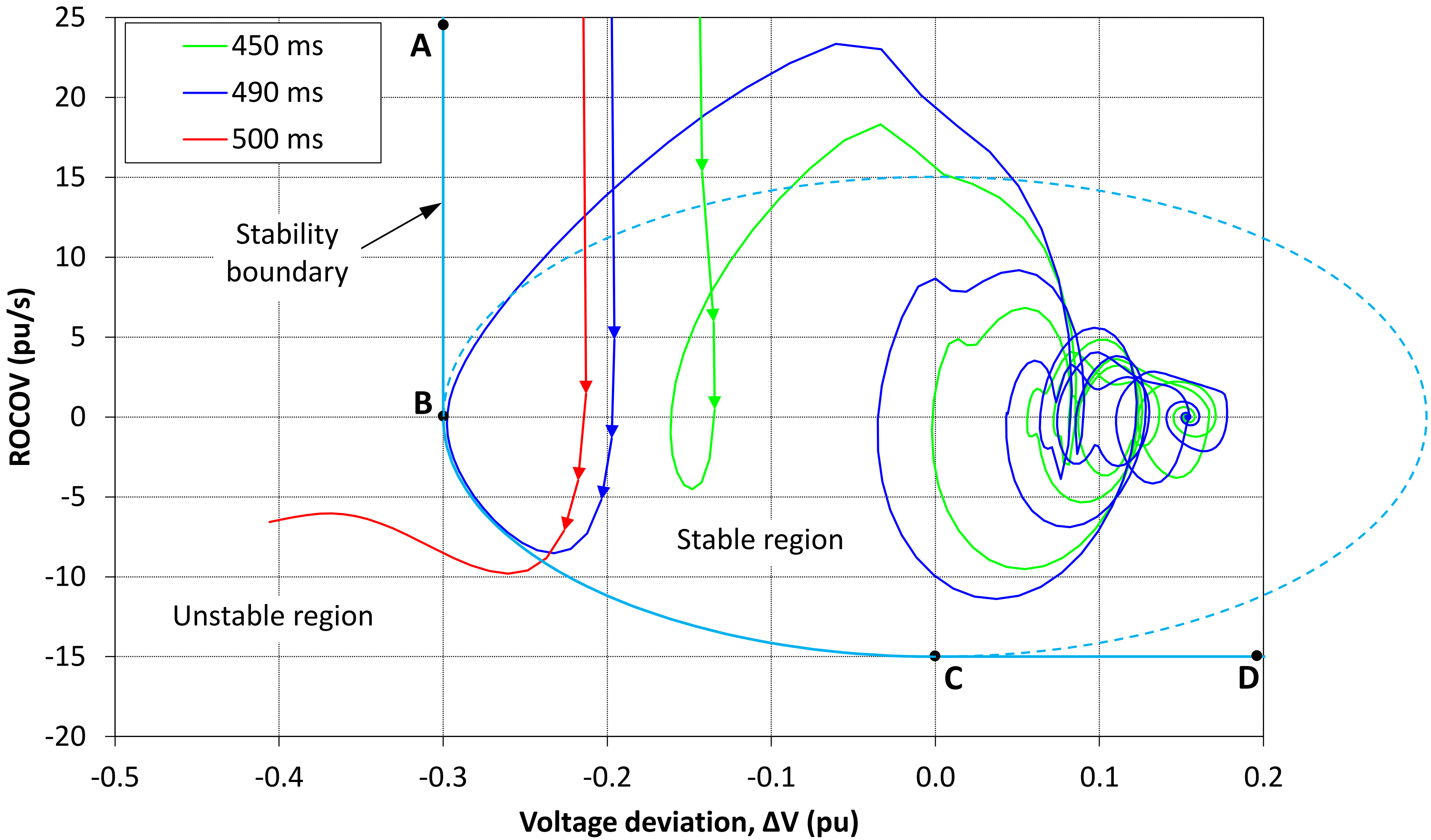
One machine to infinite bus (OMIB) system with the initial steady-state power flow solution

Concept of the Proposed Method



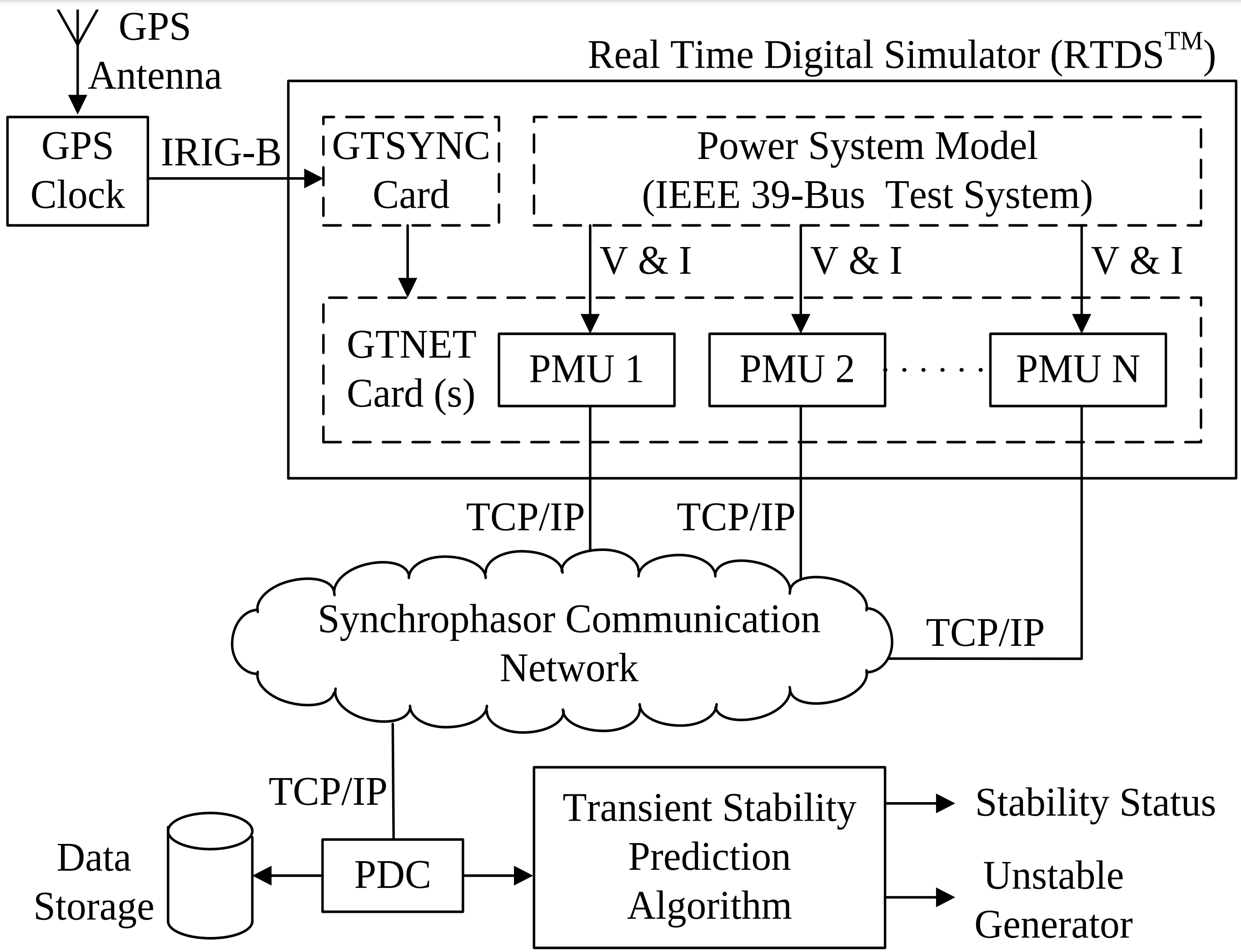
Variations of rotor angle and voltage magnitude following a fault

Concept of the Proposed Method



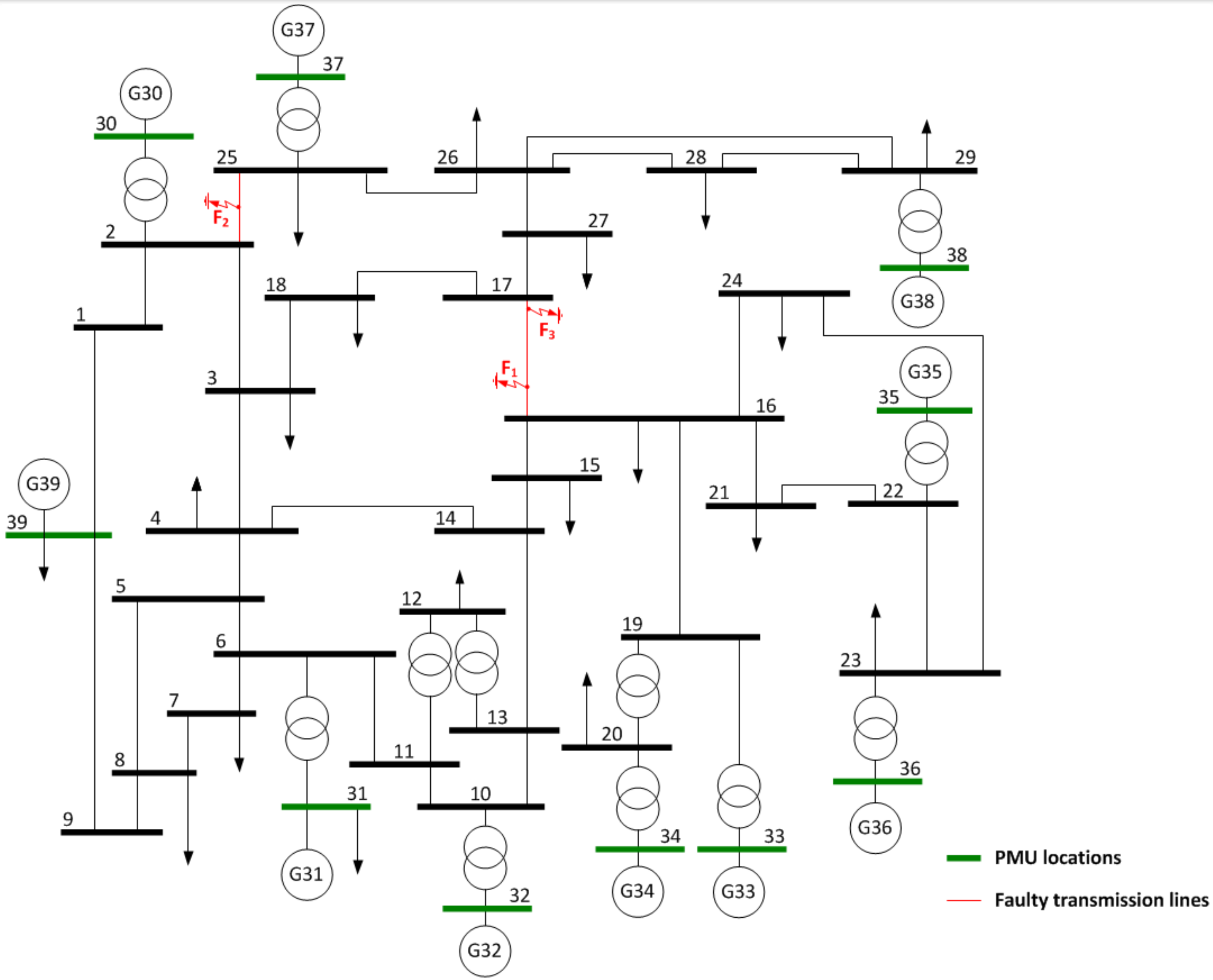
Plot of ROCOV vs. ΔV

Laboratory-Scale Test Setup

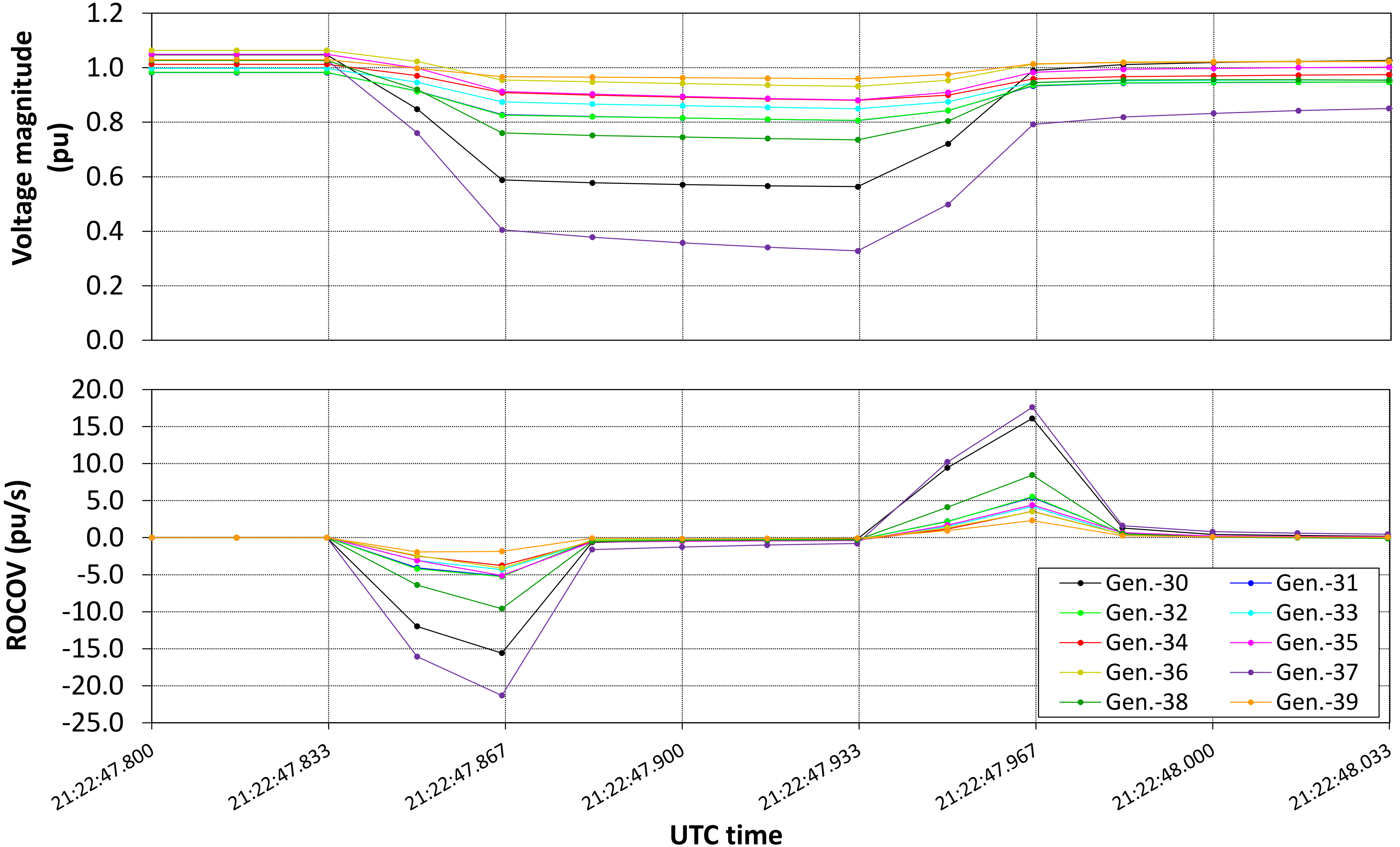


RTDS^{TM} and laboratory scale synchrophasor network

Simulation Results : IEEE 39-Bus Test System

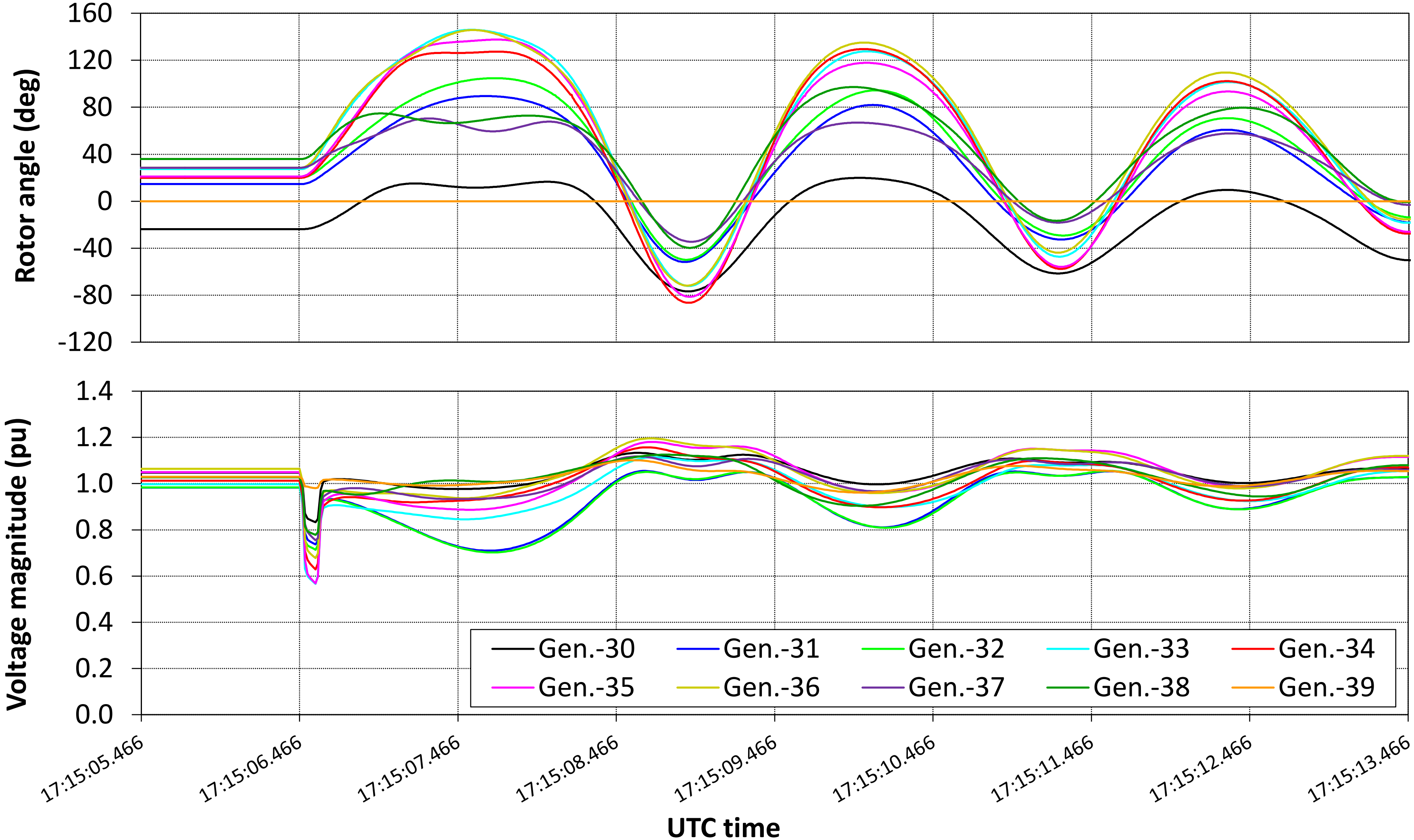


Simulation Results : Fault Detection



Variations of voltage magnitude and ROCOV of 6 cycles fault

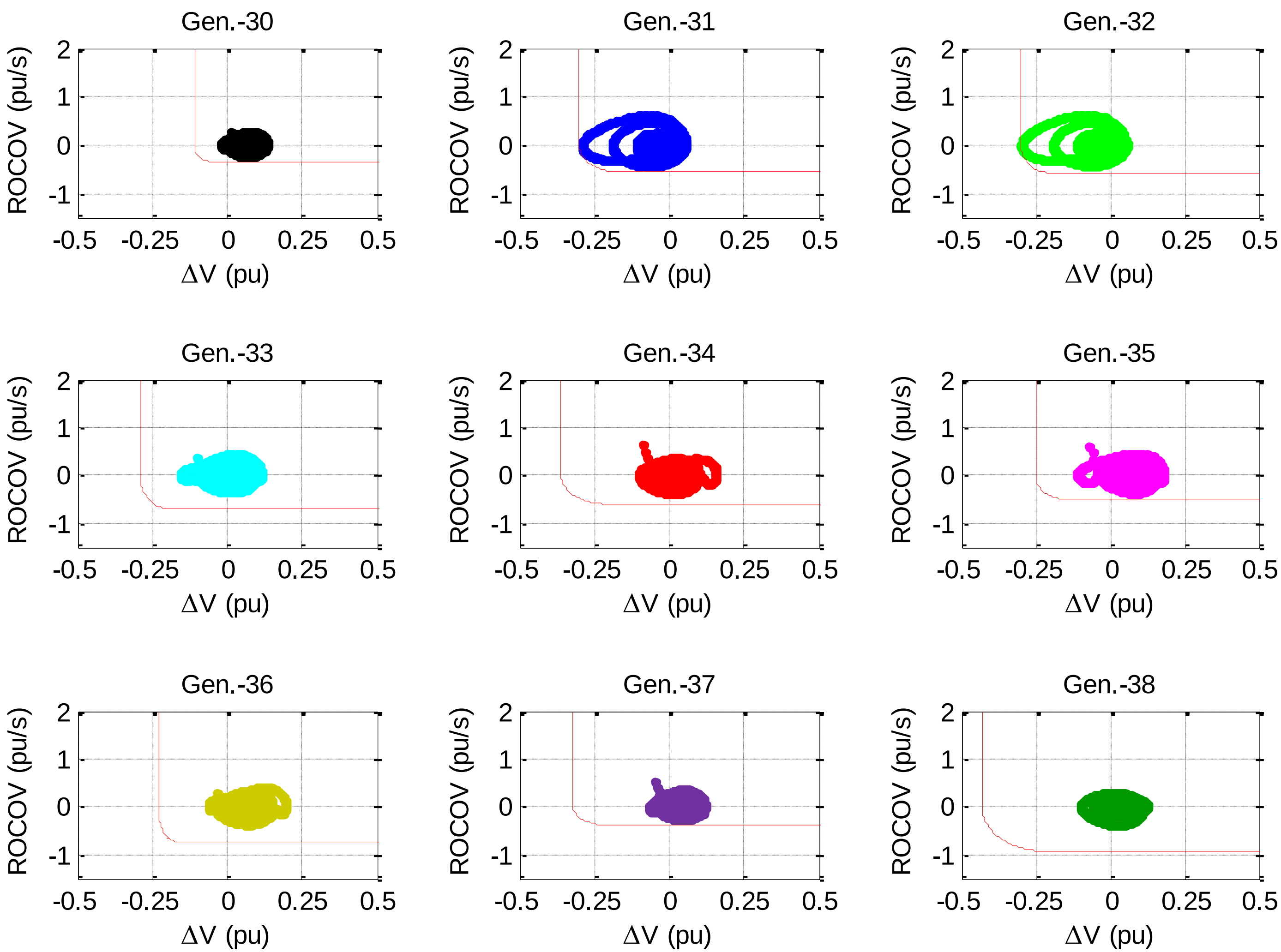
Simulation Results : Stable Case (F_1)



Variations of rotor angle and voltage magnitude

Fault on line 16-17 (25% of the length) cleared by removing the line after 6 cycles

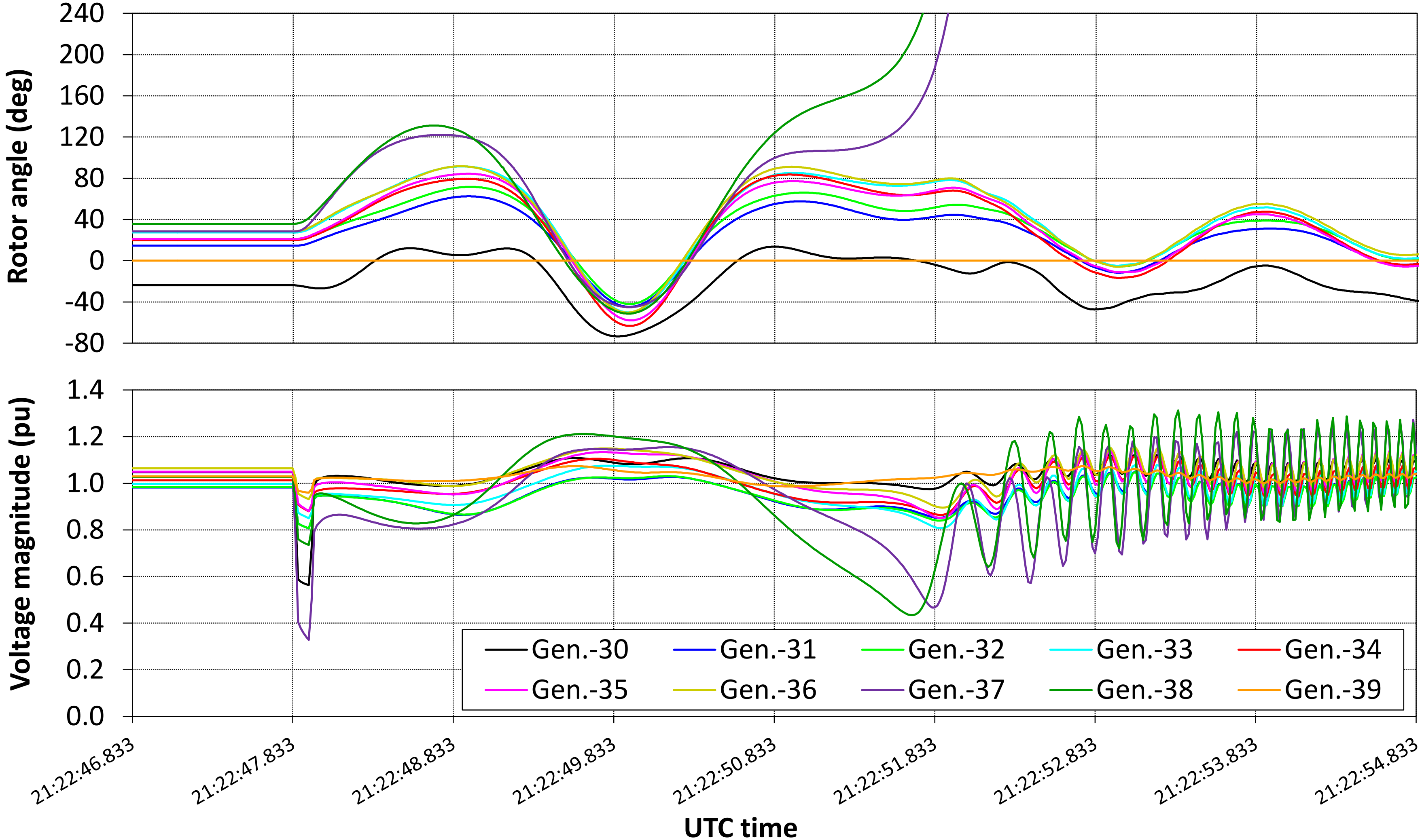
Simulation Results : Stable Case (F_1)



Variations of ROCOV vs. voltage deviation

Fault on line 16-17 (25% of the length) cleared by removing the line after 6 cycles

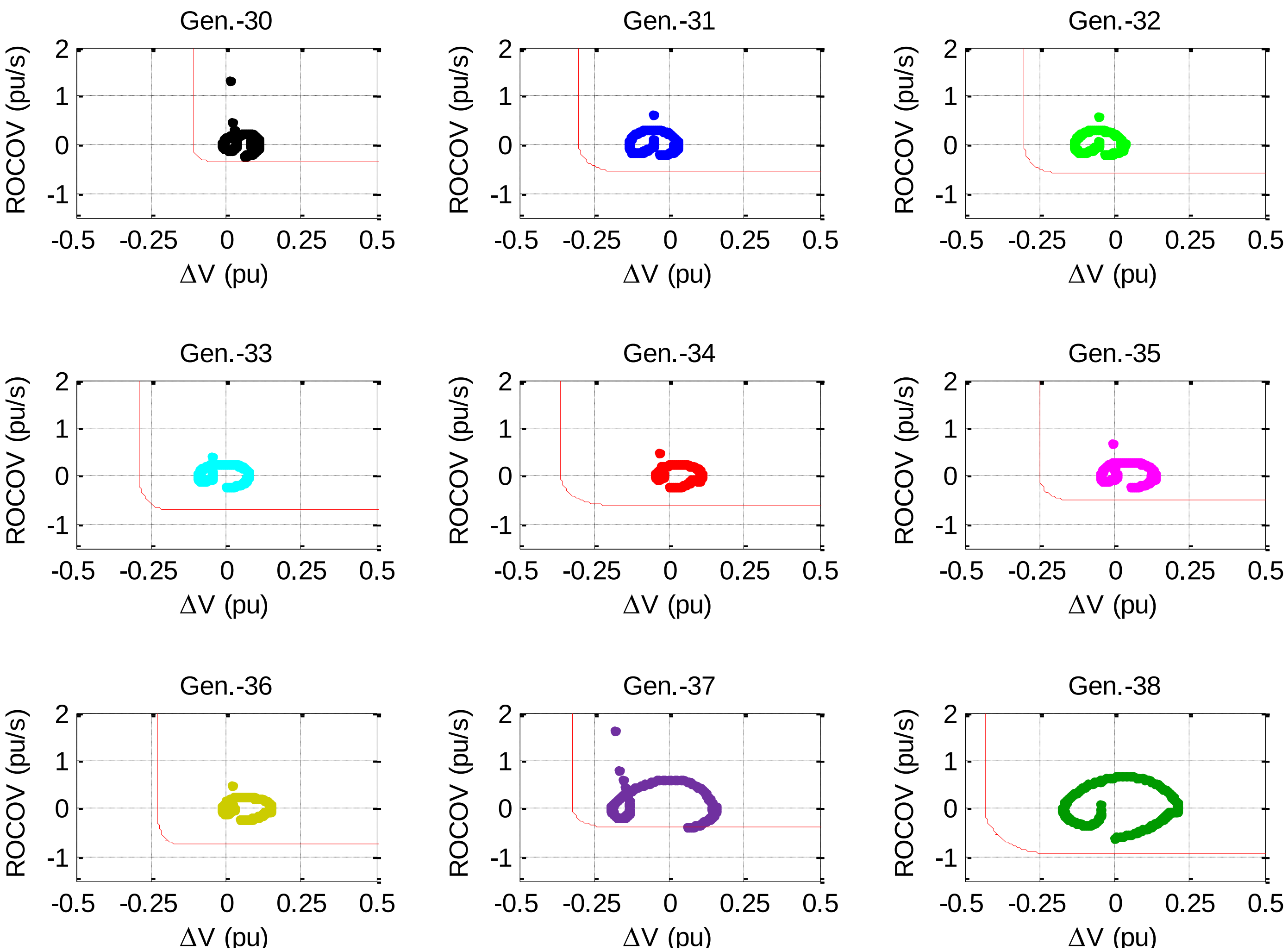
Simulation Results : Unstable Case I (F_2)



Variations of rotor angle and voltage magnitude

Fault on line 2-25 (50% of the length) cleared by removing the line after 6 cycles

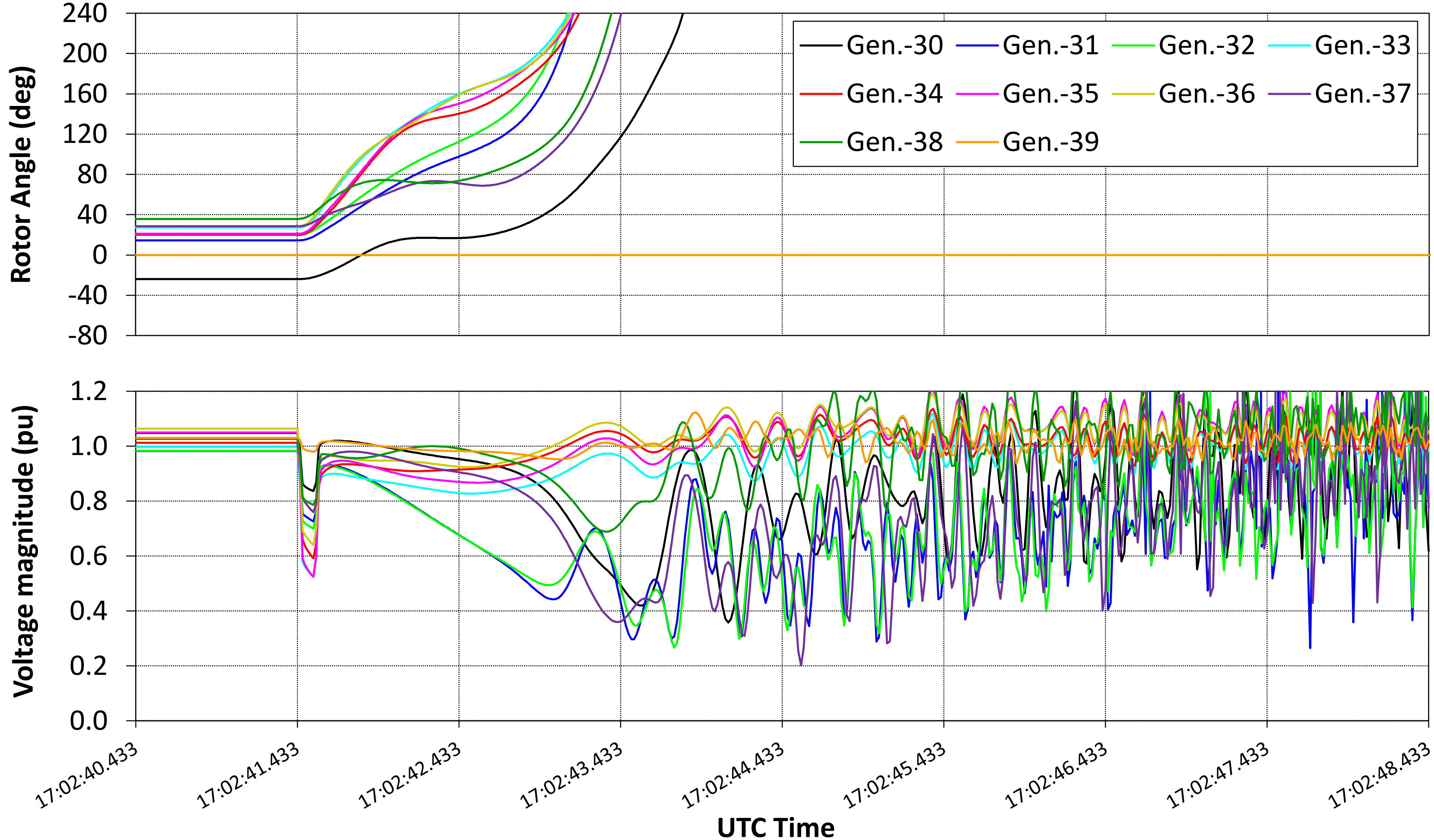
Simulation Results : Unstable Case I (F_2)



Variations of ROCOV vs. voltage deviation

Fault on line 2-25 (50% of the length) cleared by removing the line after 6 cycles

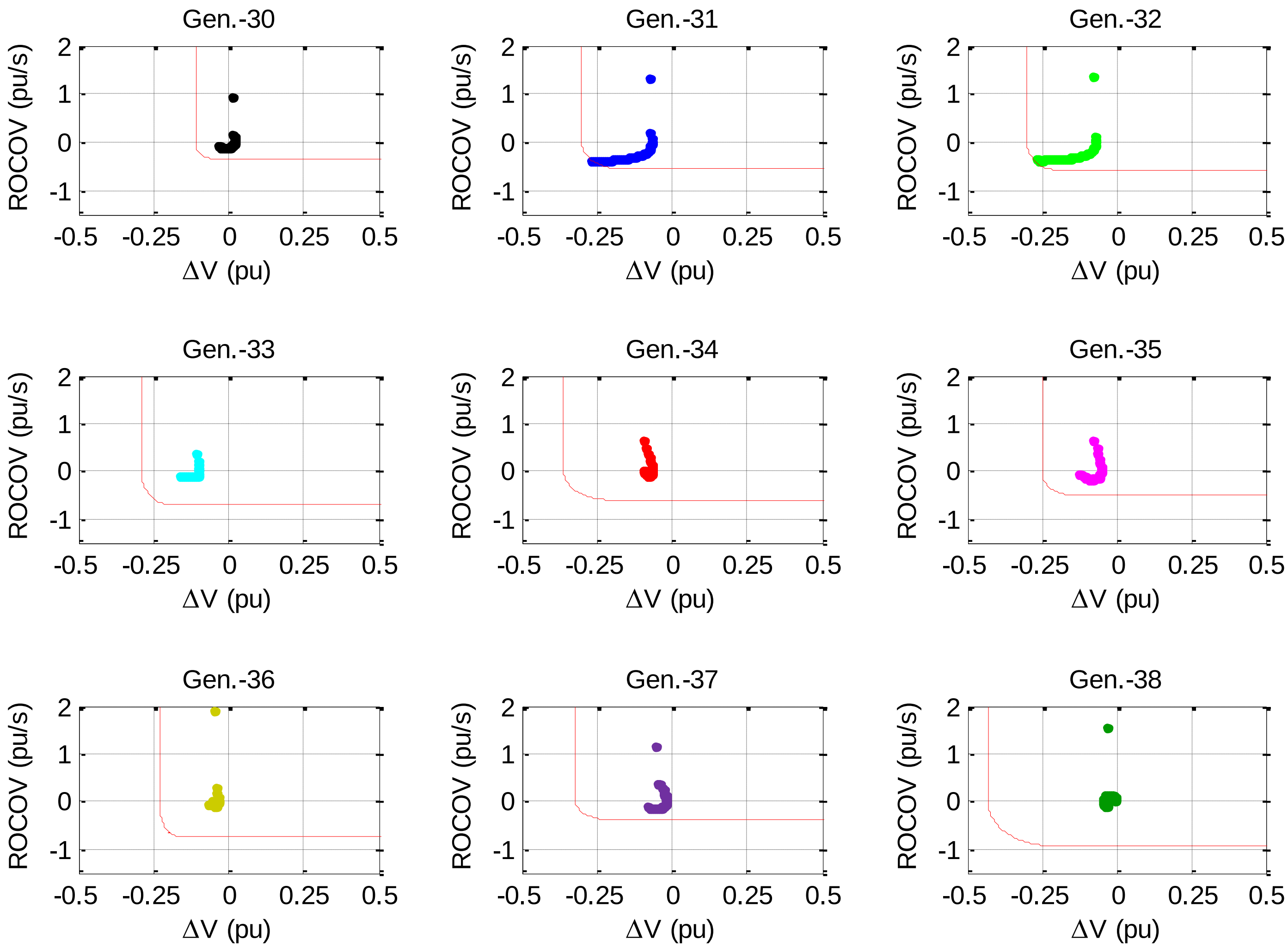
Simulation Results : Unstable Case II (F_3)



Variations of rotor angle and voltage magnitude

Fault on line 16-17 (95% of the length) cleared by removing the line after 6 cycles

Simulation Results : Unstable Case II (F_3)



Variations of ROCOV vs. voltage deviation

Fault on line 16-17 (95% of the length) cleared by removing the line after 6 cycles

Simulation Results : Fault Types

Fault type	Condition	Predicted as stable	Predicted as unstable	Early prediction advantage* (ms)	Overall accuracy (%)
Single-phase to ground	Stable case	219/219	0/219	--	100.0
	Unstable case	0/6	6/6	619	
Phase-to-phase	Stable case	200/200	0/200	--	100.0
	Unstable case	0/25	25/25	601	
Phase-to-phase to ground	Stable case	176/177	1/177	--	99.6
	Unstable case	0/48	48/48	705	
Three-phase to ground	Stable case	106/108	2/108	--	99.1
	Unstable case	0/117	117/117	653	

*** Mean values of early prediction time advantage, which is defined as the difference between the time when the proposed algorithm predicts an unstable condition and the time when the instability is declared when applied the criterion given in the transient stability assessment tool (TSAT)**

Simulation Results : Topology Changes

Topology change	Condition	Predicted as stable	Predicted as unstable	Early prediction advantage* (ms)	Overall accuracy (%)
Line 5-8 out of service	Stable case	230/231	1/231	--	99.7
	Unstable case	0/69	69/69	717	
Line 22-23 out of service	Stable case	256/258	2/258	--	99.3
	Unstable case	0/42	42/42	630	
Line 25-26 out of service	Stable case	215/215	0/215	--	100.0
	Unstable case	0/85	85/85	603	

*** Mean values of early prediction time advantage, which is defined as the difference between the time when the proposed algorithm predicts an unstable condition and the time when the instability is declared when applied the criterion given in the transient stability assessment tool (TSAT)**

Conclusion

- A novel transient stability prediction approach based on the ROCOV-ΔV characteristics of the post-fault voltage magnitudes obtained from PMUs located at the generator terminal buses was proposed
- RTDS simulation studies carried out for the IEEE 39-bus test system showed over 99% overall prediction accuracy under all types of faults
- The average early prediction time advantage compared to the rotor angle separation methods was more than 600 ms, which allows more time to take an appropriate corrective action
- Furthermore, the proposed method was shown to be robust for random changes in pre-fault generations and loads as well as network topology changes

Thank you

Q & A