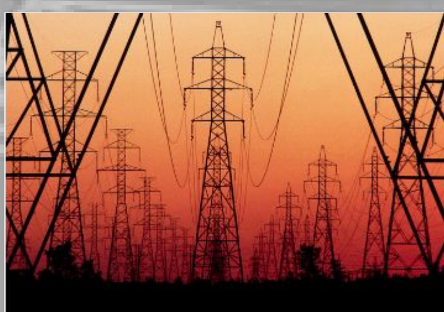

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RVII Testing on Tenaga Power System

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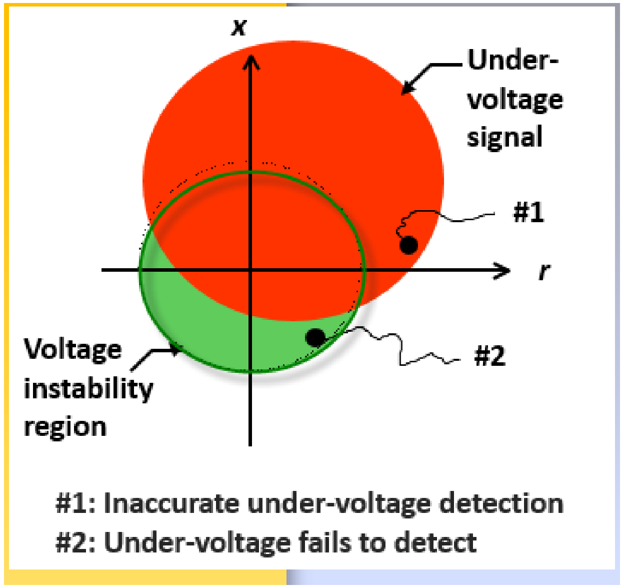
NASPI International Synchrophasor Symposium
Atlanta, Georgia

March 22-24, 2016

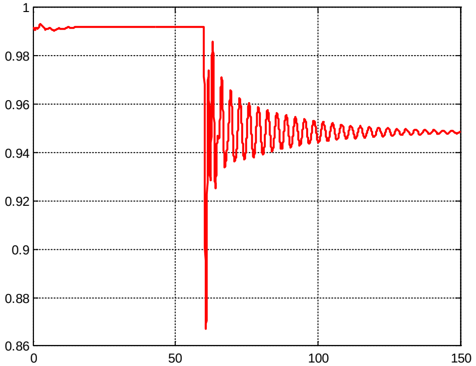
RVII Foundation

Fundamentally, local voltage instability detector

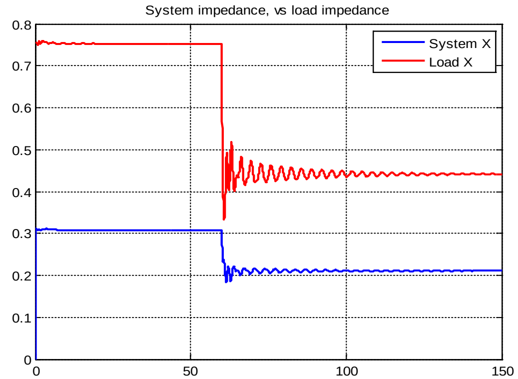
- Just like a relay, real time computation that uses only local information (no network model needed)
- Unlike a relay , able to avoid point #1 (figure a & b), and includes point #2



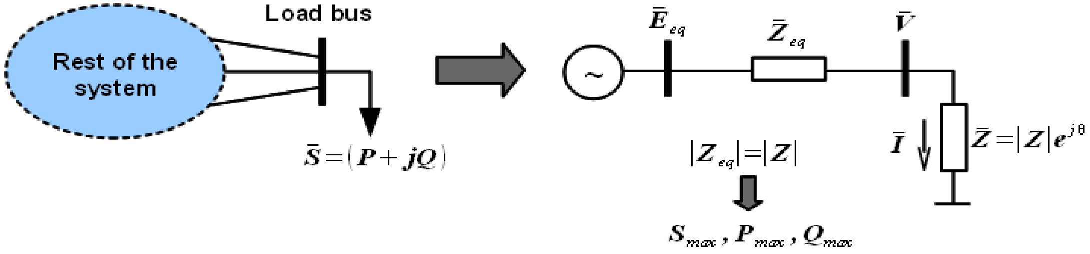
(a)



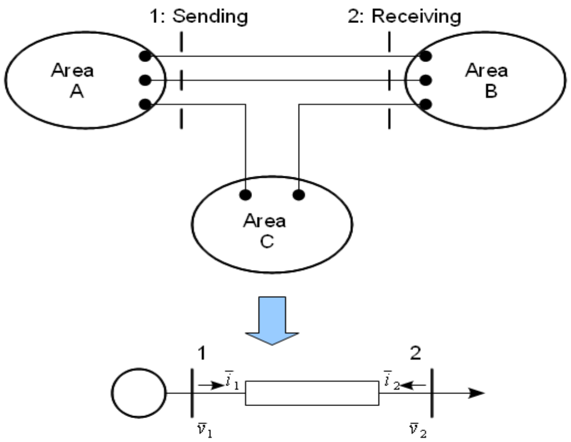
(b)

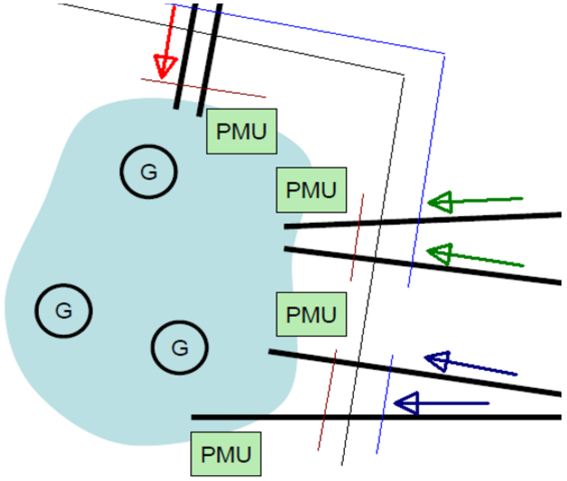


RVII Algorithm Types



- Bus RVII
- Area RVII
- Corridor RVII
  - Leverages Bus RVII and analytical computation of the corridor to improve quality of Equivalent parameters



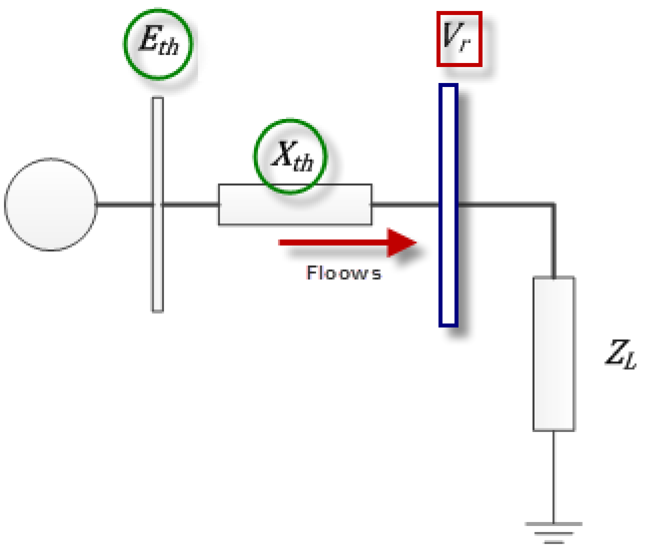


Uses of RVII's System View

- Three stage approach to meet objectives

- Real Time voltage instability **DETECTION**
- **WHAT IF** analysis:
  - Extrapolation
    - Margin to Instability
    - Margin to Operating boundary

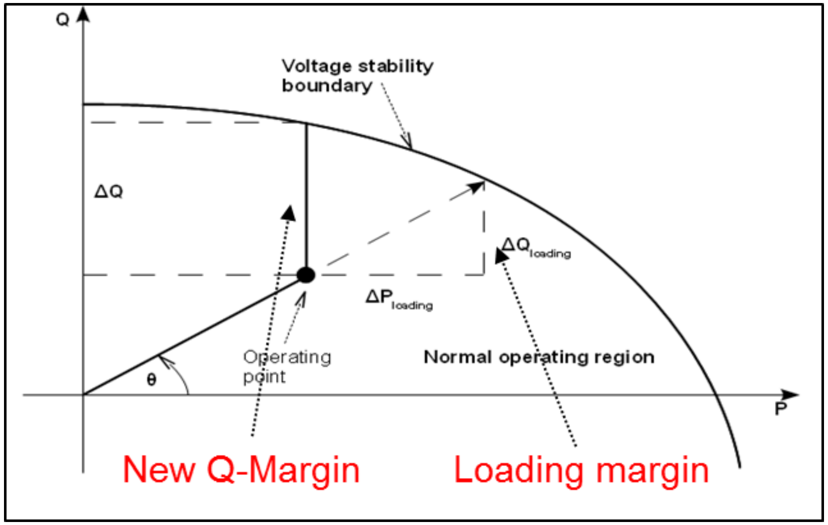
  - Predictions
    - Margin to Instability
    - Margin to Operating boundary

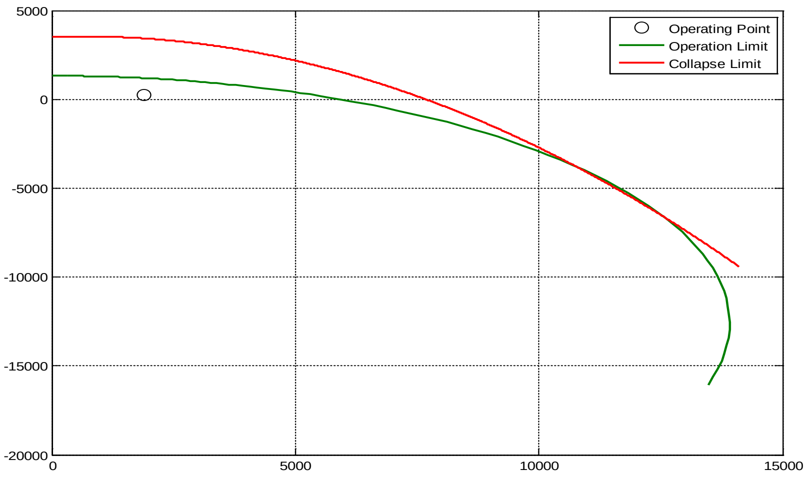


RVII Margins

Extrapolation vs. Prediction

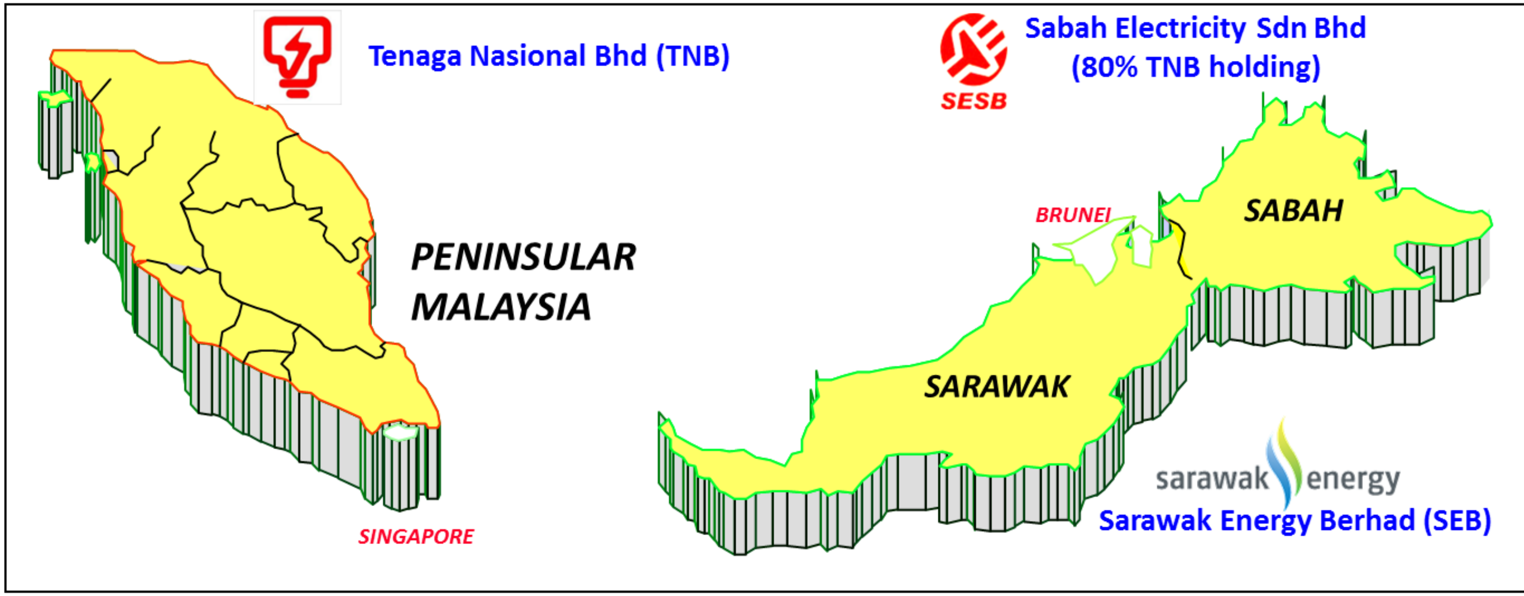
- **Extrapolation**
  - Constant power factor load increase until boundaries reached
  - System equivalent params kept fixed
- **Prediction**
  - Additional information used (hybrid of RT model-less, and much slower model-based)
    - To define more accurately load change path
    - To update equivalent parameters as a function of load increase
    - Plot reactive power margin
- RVII implements Extrapolation





Problem Background

- Three main power utilities in Malaysia: TNB, SESB & SEB



Peninsular Malaysia

Customers	~8.11mn
Installed Capacity	21,954 MW
TNB Capacity	11,824 MW
Max Demand	17,000 MW

sarawak energy **Sarawak**

Customers	0.574 mn
Installed Capacity	2,930MW
SEB Capacity	1,352 MW
Max Demand	1,758 MW

SESB **Sabah**

Customers	0.510 mn
Installed Capacity	1,241 MW
SESB Capacity	449 MW
Max Demand	917MW

TENAGA NASIONAL Better. Brighter.

QUANTA TECHNOLOGY

Problem Background

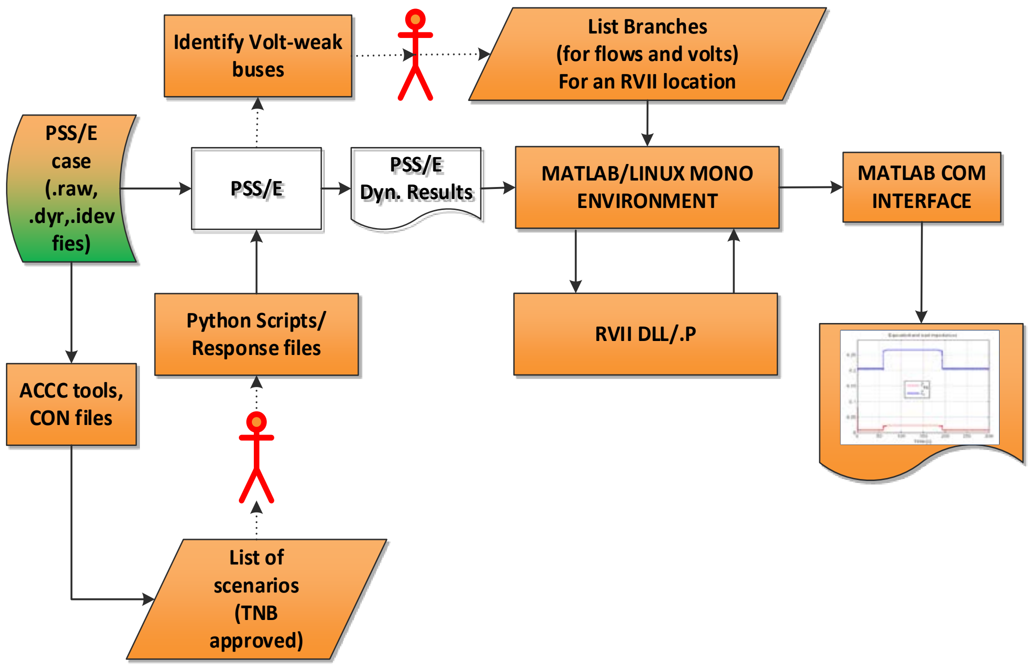
1. Large transfer of power into Central Area (high load demand)
2. Least cost generation sources away from load centre
3. Difficulty in securing new power corridors (land, public objection, NIMBY)
4. Risk of system instability in the event of loss of major transmission corridors

TNB Testing Background

- Quanta Technology(QT) and Tenaga Nasional Berhad (TNB) worked together on integrating RVII functionality with their OpalRT simulator, which uses a complete transient stability model of TNB bulk power system.
- Testing was extensive, using a combination of
  - Time domain transient simulations (PSS/E) in a preliminary tuning and testing stage
  - Software in the loop simulations (OpalRT)
- Tests clearly indicate the capability of RVII to correctly distinguish voltage stable from unstable cases
  - Referring to Slide #2, it correctly characterizes points #1 and points #2
  - For example, RVII was able to detect proximity to voltage instability when relatively high voltages would have masked the actual proximity to voltage collapse if viewed only through SCADA data (or under-voltage relays).
- Currently implementations of RVII algorithm in TNB's embedder controllers are being carried out for Hardware in the loop testing.

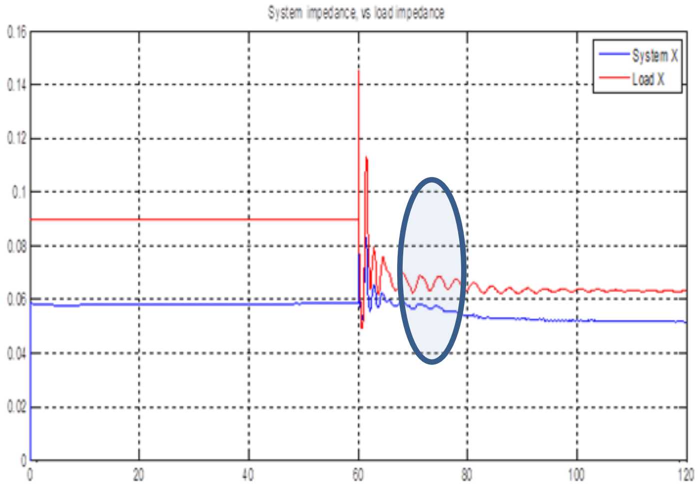
Offline Testing Environment

- Prior to RT Deployment, RVII deployed in test environment
  - Comprehensive TNB transient stability model used
    - PSSE – based
  - Establish RVII locations, suitable inputs, and verify accuracy
- At TNB
  - OpalRT-based "deployment"
    - Entire TNB network
    - Physical and Virtual PMUs
  - Next Step – in progress:
    - Implementation in TNBs embedded controller
    - Hardware in the loop setup

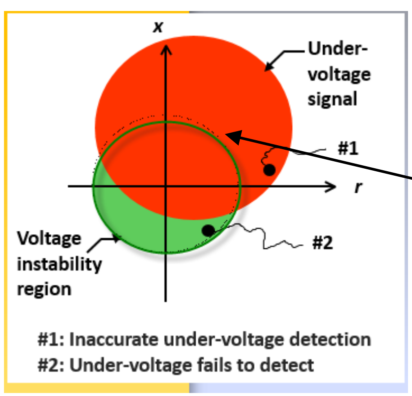


Input: PSSE case; output plots of Thevenin and "Load" Impedance

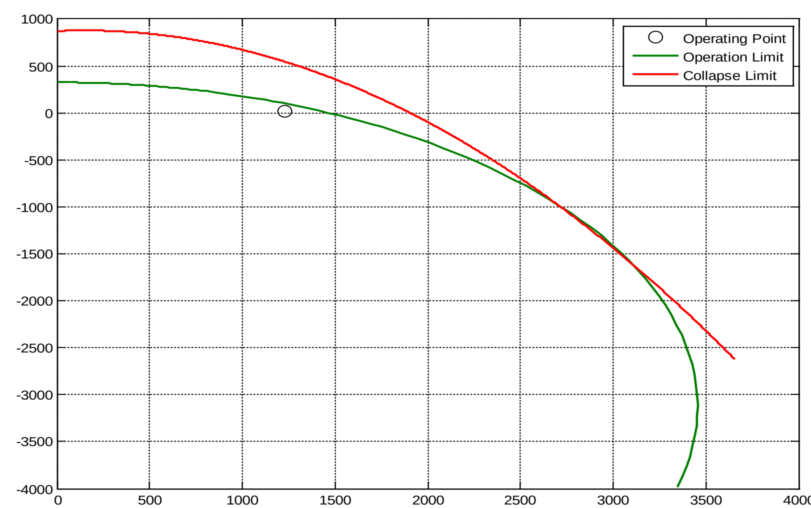
Example 1: Interface @ base Power Transfer



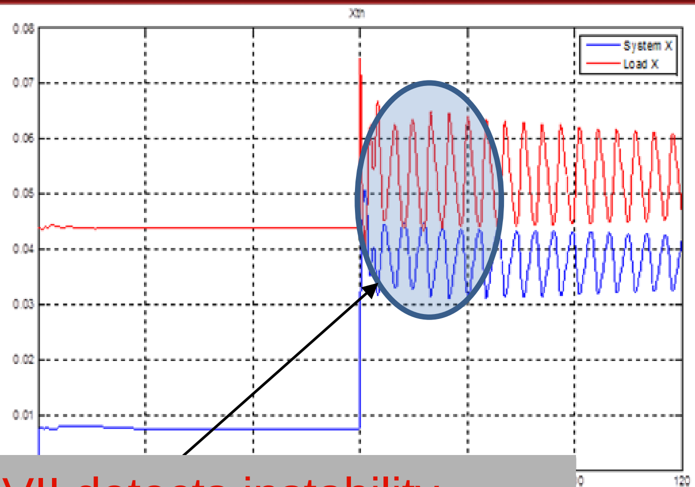
- Impact of outage at **Zero Transfer Level** on critical TNB interface
- This references post - outage condition
- Low voltages in the vicinity of the study zone, but
- Clear separation between Thevenin and Load Impedances
  - The conclusion: system voltage stable
  - Fig. below shows system operating further away (wider margin) from operational or collapse limits.



Note: in this case voltage was relatively low



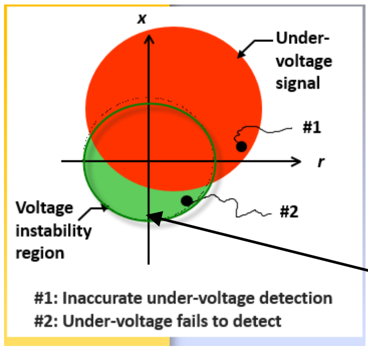
Example 2: Interface @ Maximum Power Transfer



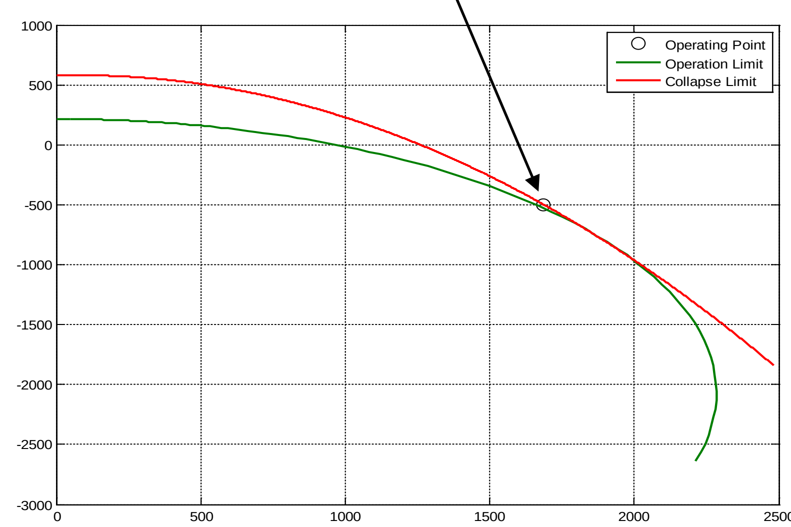
RVII detects instability

- Impact of outage at **Interface Transfer limit.**
- Path TTC limited by transient stability problem.
- RVII successfully detects instability
- System is operating with close to zero margins, at the boundary of instability limits.

System operating at limits



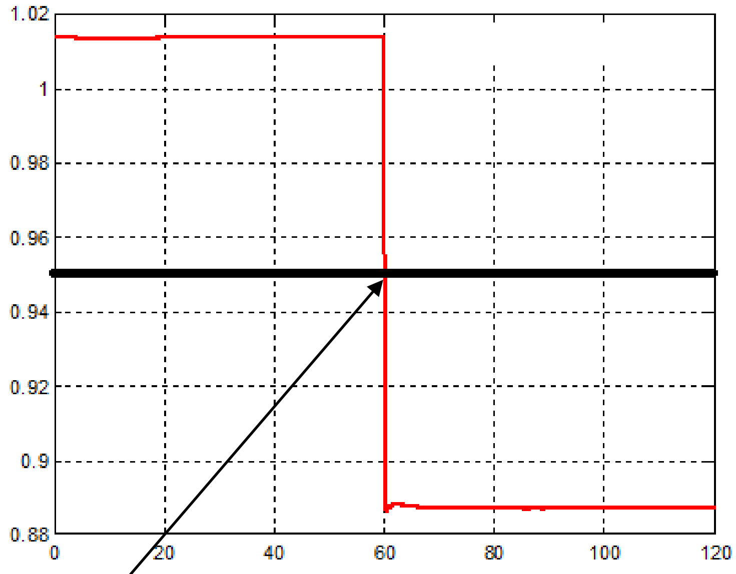
Note: in this case voltage was relatively high

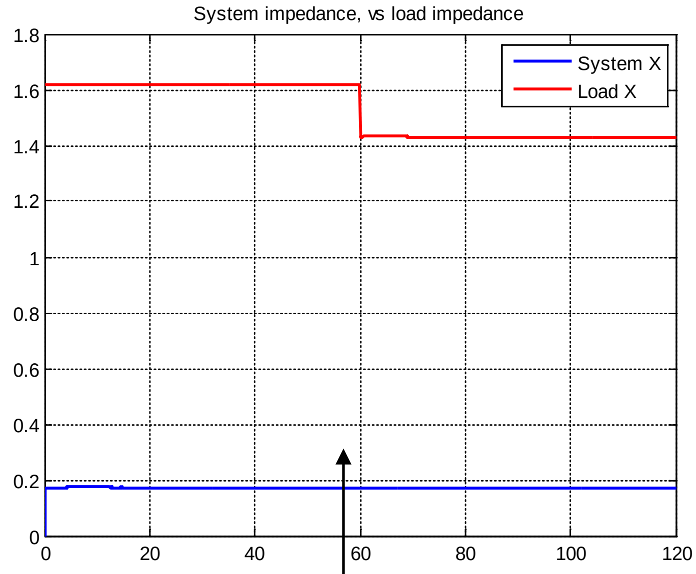


Under-voltage Relay Example

Double Contingency to Load Pocket

- Drastic action may be taken on voltages of 0.95 p.u to prevent instability.
- RVII would show, however, that system is far from collapse (verified by PSS/E time domain simulations).



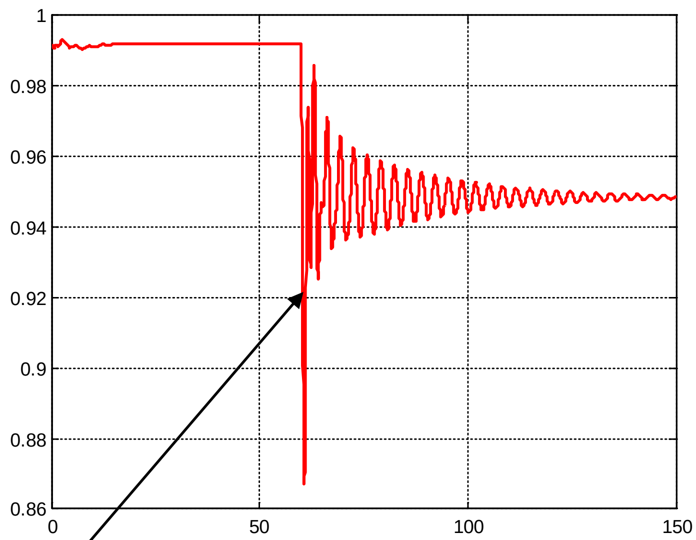


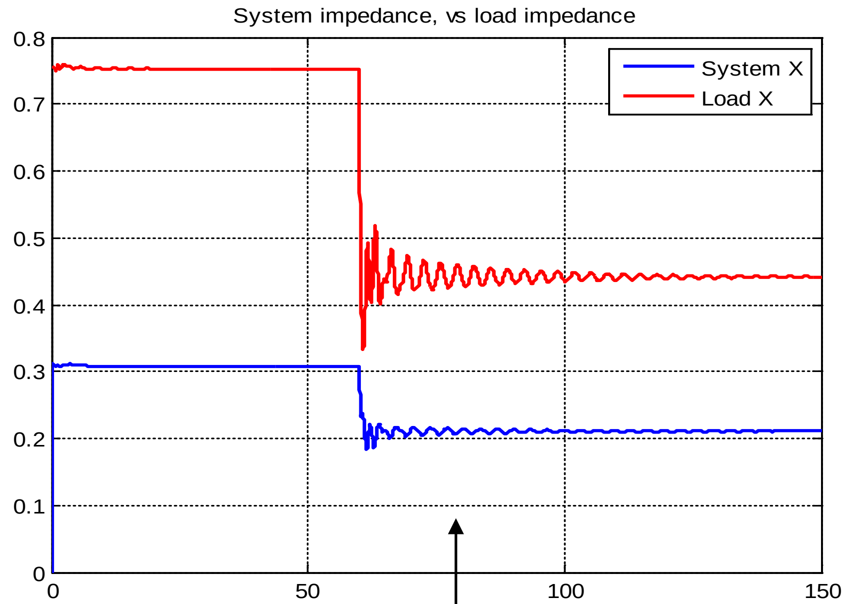
UVLS Triggers

Very insignificant change in Thevenin Impedance

Stability Detection at Brink of UVLS Trigger

- RVII successfully identifies separation between system and load impedances, indicating a stable system condition.
- Absent RVII, drastic under-voltage action might be taken at voltages of 0.95 pu to prevent instability.



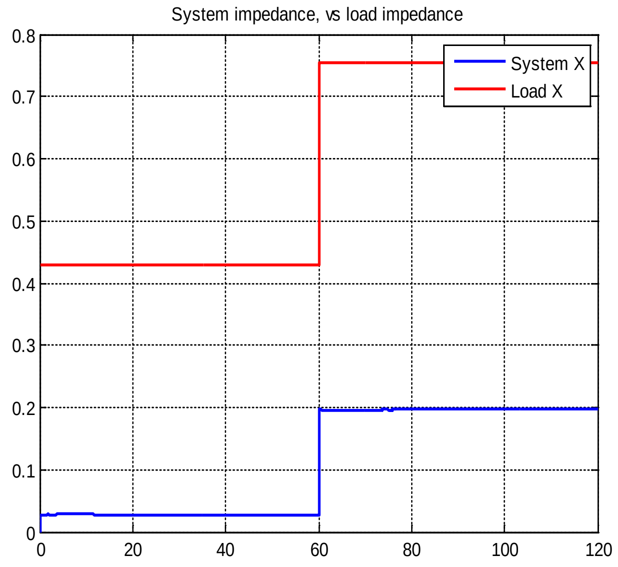


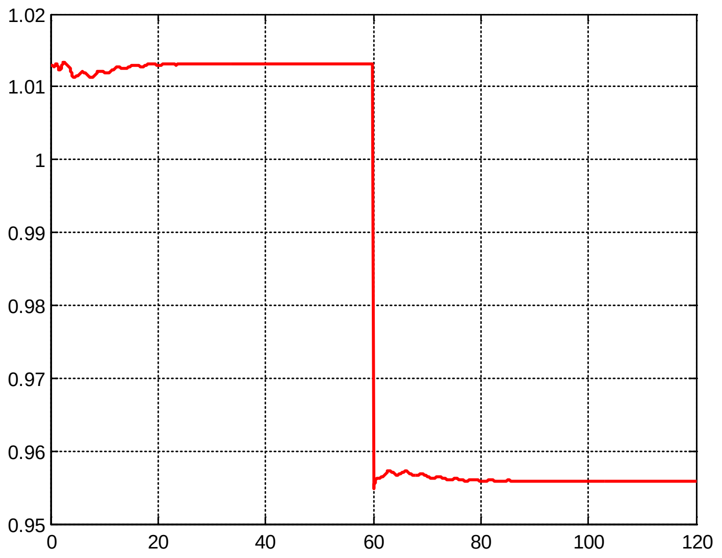
UVLS Triggers

Insignificant change in Thevenin Impedance

Loss of Source to Radial Load Pocket

- RVII successfully identifies separation between system and load impedances, indicating a stable system condition even in scenarios with loss of source supply to radial load pocket.
- Also verified through simulation (PSS/E), is the impact of additional dynamic compensation triggered within the load pocket that moves the system away from instability.





Concluding Remarks

- Model-free algorithm, like RVII, requires extensive validation via simulation ahead of deployment
- A Real-Time test- bed, like the one available at TNB, or a batch simulation testbed as used in house is crucial to validate results
- RVII in a pure model-free implementation is suitable for instability Detection and Extrapolation (both important when close to instability); Prediction (which is important when far from instability) requires a hybrid approach
- Work being pursued in direction of contingency- based RVII -- showing promising results.
- Several applications leveraging benefits of RVII results, such as RVII-triggered load shedding, are currently being validated.

Thank You!

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