REAL TIME VOLTAGE STABILITY MONITORING OF POWER SYSTEMS USING 'RT-VSM Tool'

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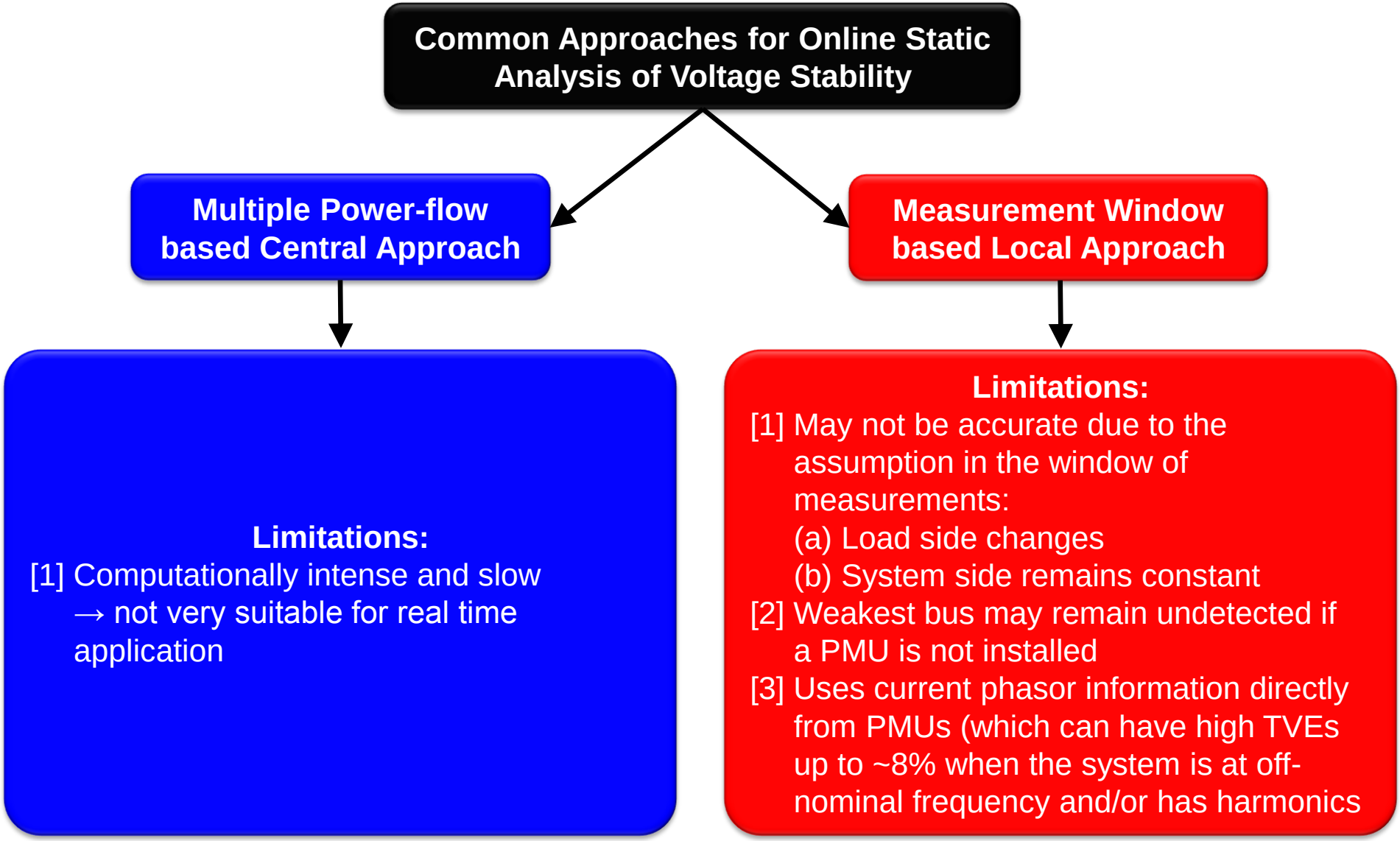
1. Motivation For A New Online Voltage Stability Monitoring Algorithm / Tool



2. Important features of the RT-VSM Algorithm

Approach	Measurement-Model based hybrid approach Needs only voltage phasor data and system topology information (current phasor data is not needed)
Computation speed	Computationally very fast, as a unique 'non-iterative' algorithm has been used → suitable for real time monitoring e.g. – In a 2.8 GHz Quad Core Computer, the algorithm time-step for IEEE-118 bus test system ≈ 70 ms
Computation accuracy	Computation accuracy is high even during the dynamic changes in the system, as window of past measurement data is not used, and no such assumption is made that considers constant parameters on the system side and varying parameters on the load side
Ease of interpretation of results	Indicates voltage stability margin of each load bus in the form of 'Voltage Stability Assessment Index (VSAI)' on a scale of '0' to '1' such that: VSAI near "0" → Voltage Stable VSAI close to "1" → On the verge of Voltage Instability

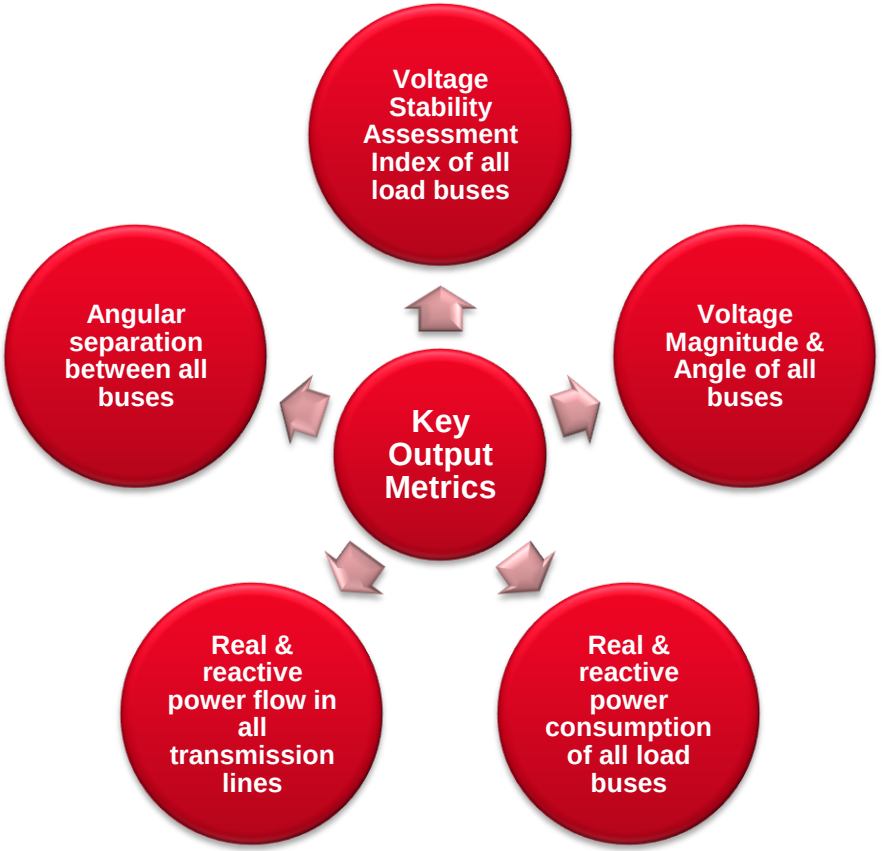
3. Important features of the RT-VSM Tool

(1) Has 2 modes –

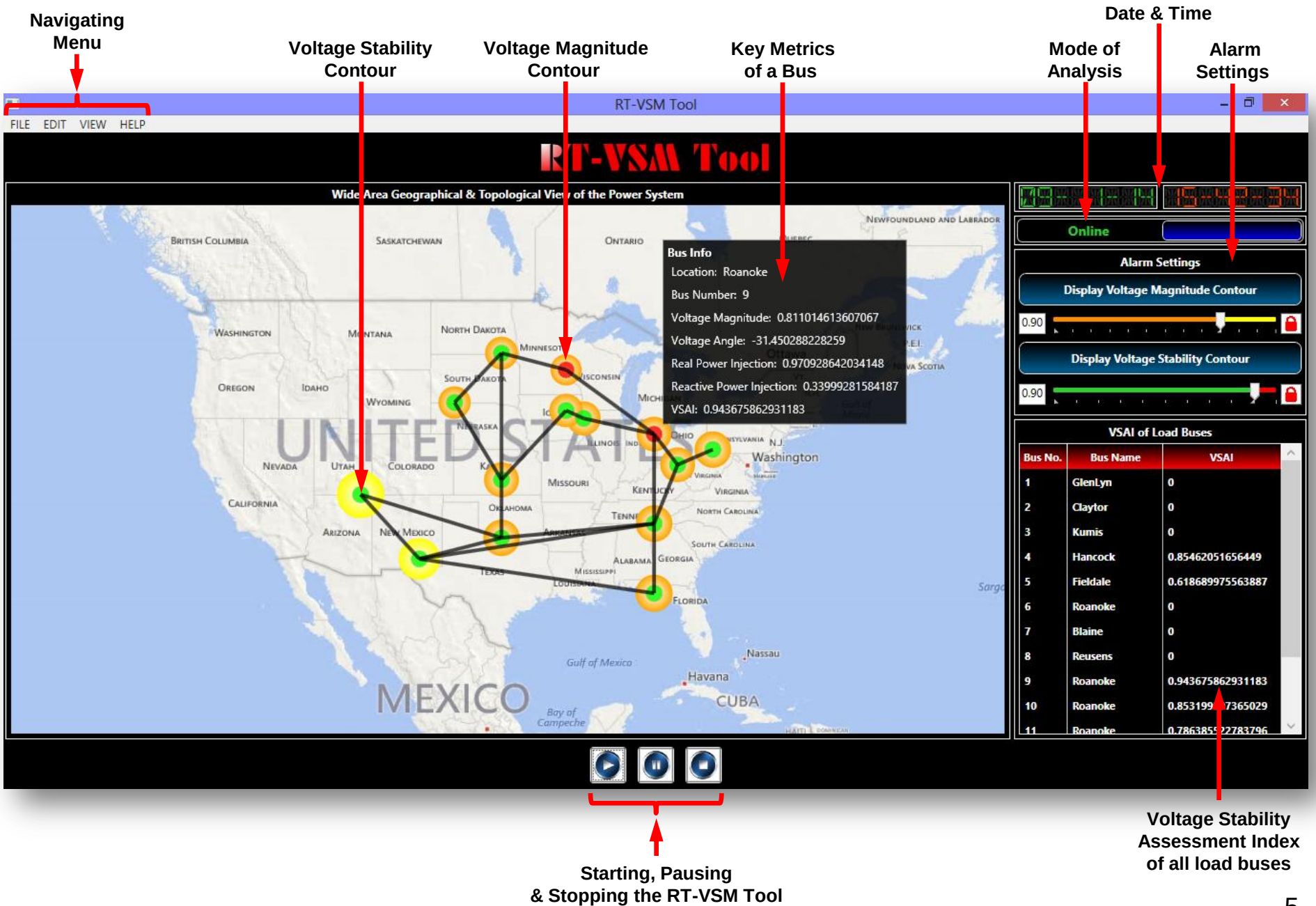
(a) Offline Mode – For pre-operation baselining purposes

(b) Online Mode – For real time monitoring purposes during operation

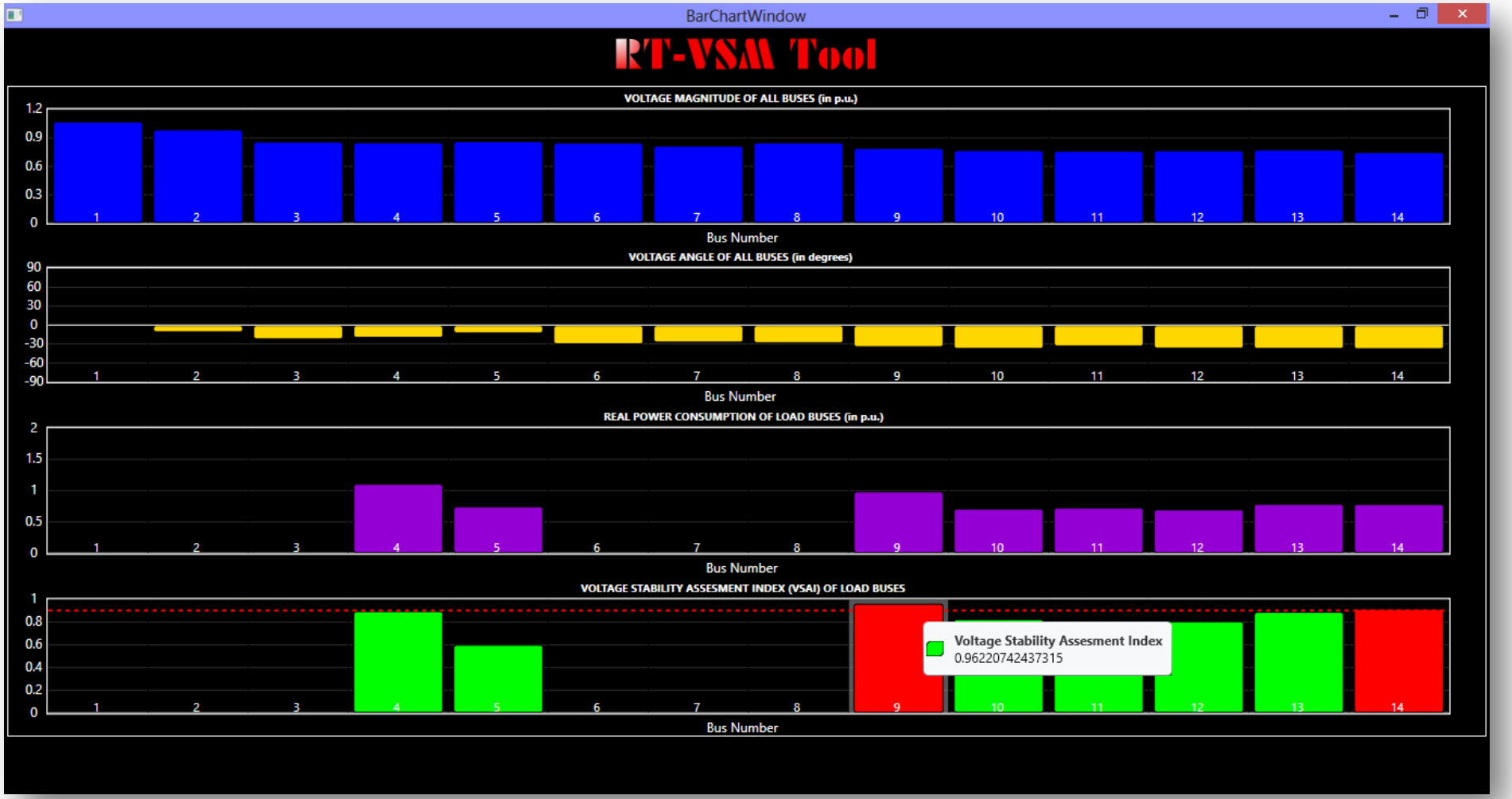
(2) Provides a simple, and yet powerful visualization of the following key metrics of the monitored power system in both 'offline' and 'online' modes to system operators –



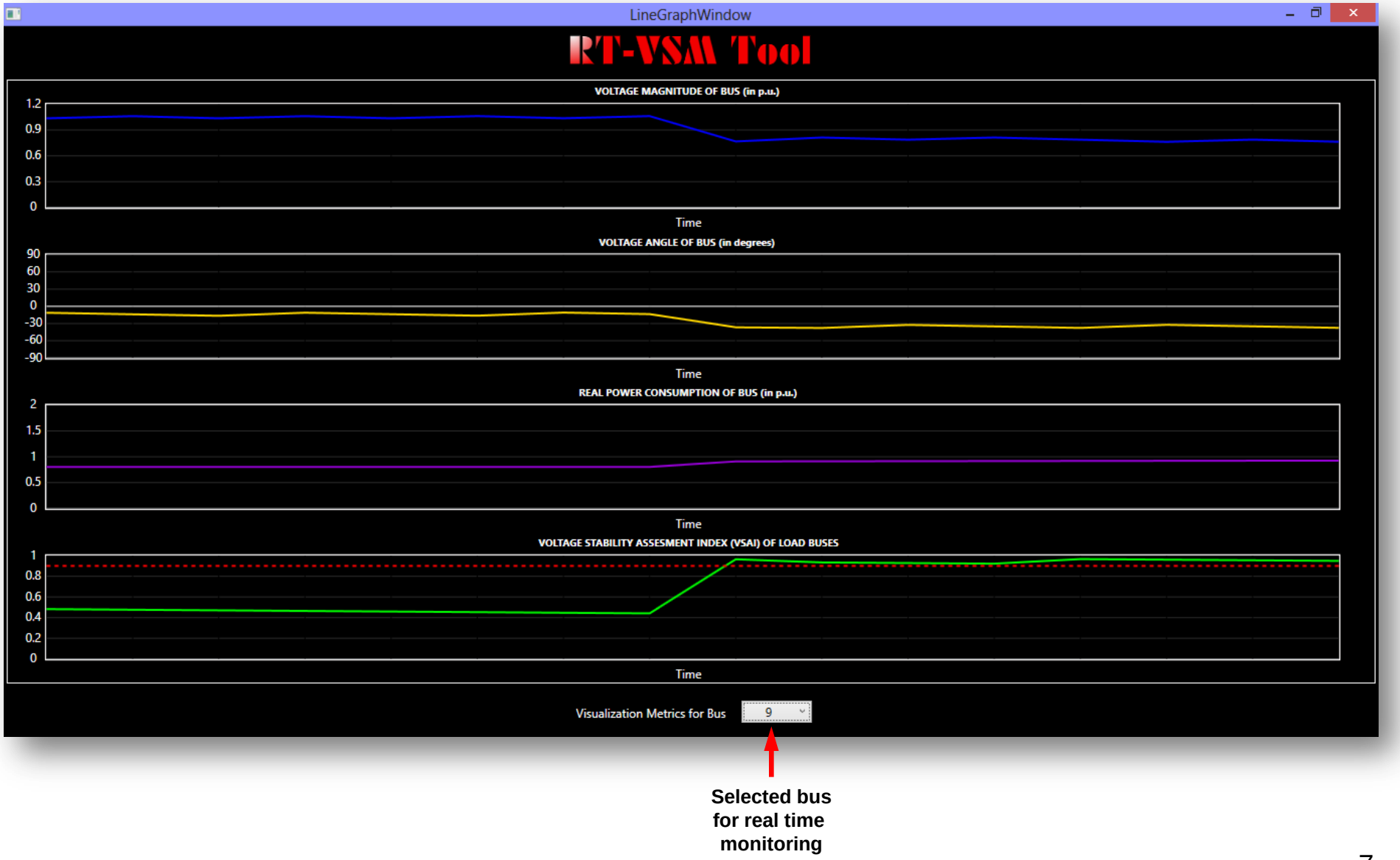
Screenshot of the main visualization dashboard of the RT-VSM Tool –



Screenshot of the wide-area metrics visualization window of the RT-VSM Tool –

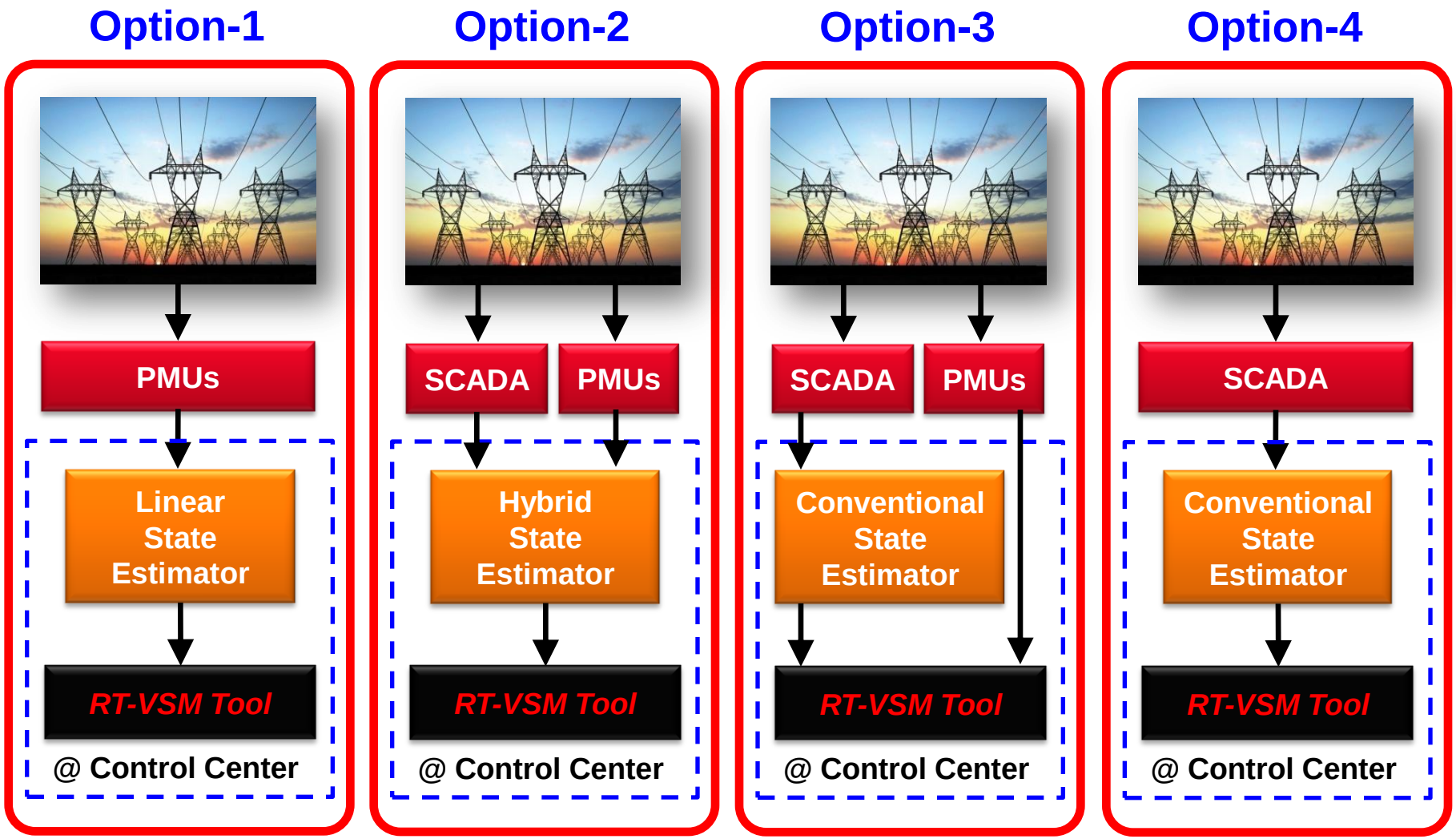


Screenshot of the bus metrics visualization window of the RT-VSM Tool –



(3) Easy to integrate in a power system control center

Options for implementation:

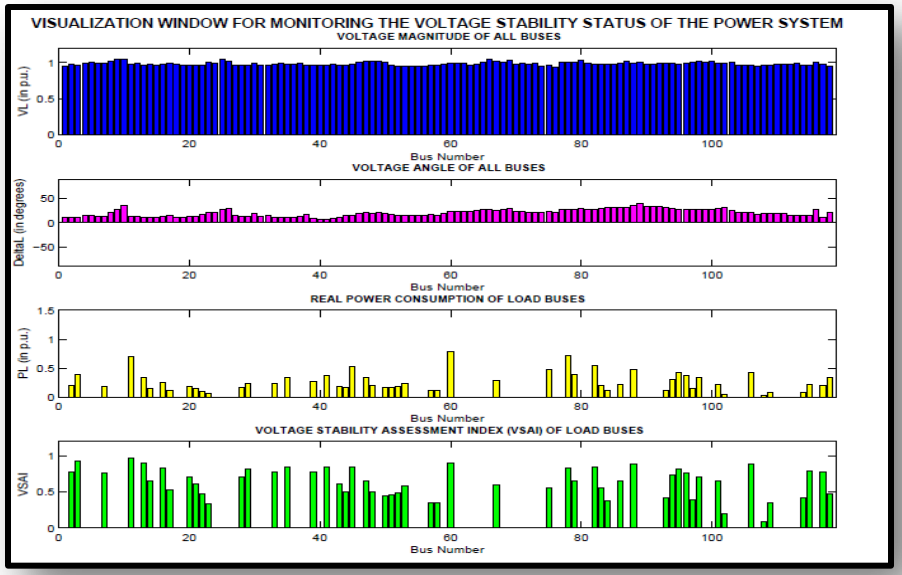


4. Offline Simulation Results

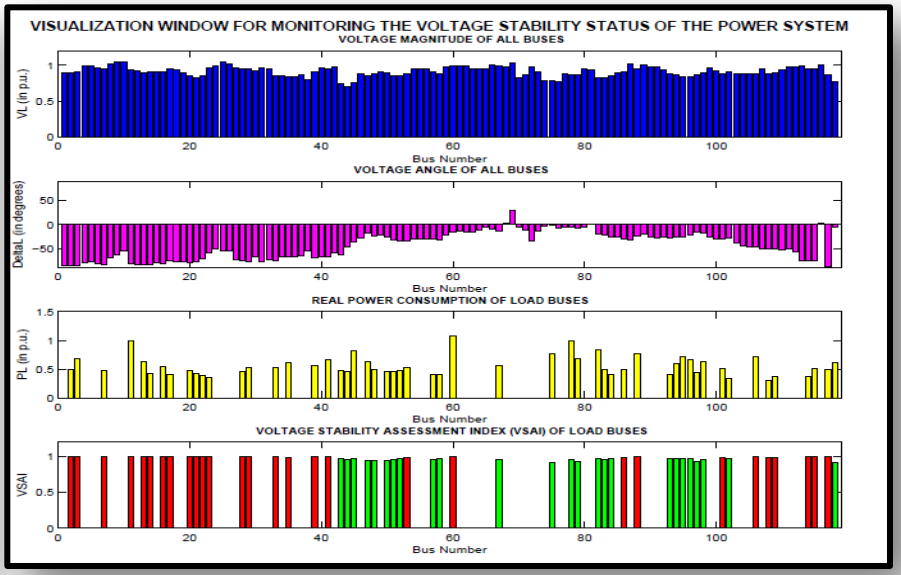
[A] Decrease in voltage stability due to increase in load (i.e. a type of small disturbance voltage stability problem) –

(1) Increase in load at all the load buses in the IEEE-118 Bus test case:

Base Case Loading



Stressed Case Loading

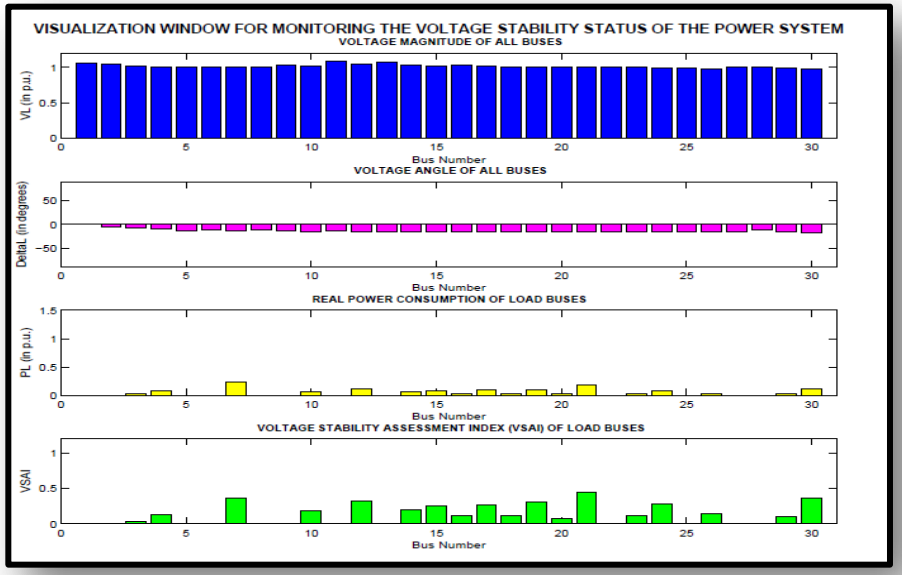


→ Increase in VSAI at the load buses (in the 4th subplot) indicate decrease in voltage stability

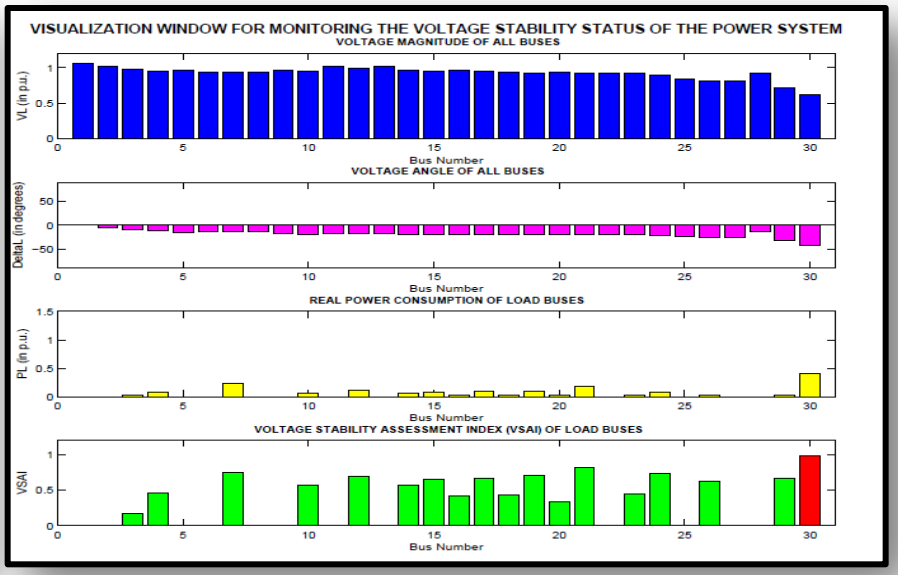
→ Power-flow fails to converge when the highest VSAI in the system is 0.995 (@ Bus-11)

(2) Increase in load at Bus-30 in the IEEE-30 Bus test case:

Base Case Loading



Stressed Case Loading



→ Increase in VSAI at the load buses (in the 4th subplot) indicate decrease in voltage stability

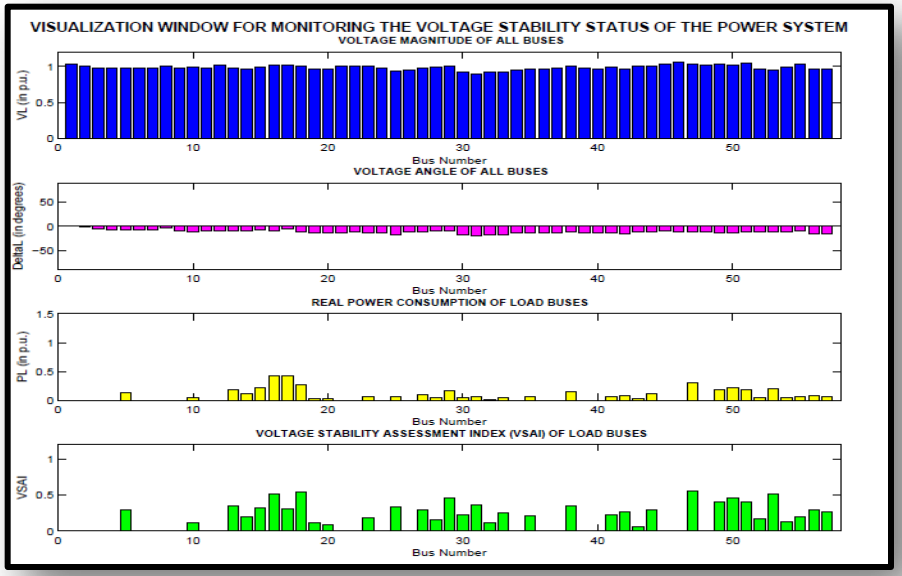
→ Weakest bus is Bus-30, indicated by the highest VSAI (0.985)

→ Power-flow fails to converge when the highest VSAI in the system is 0.985

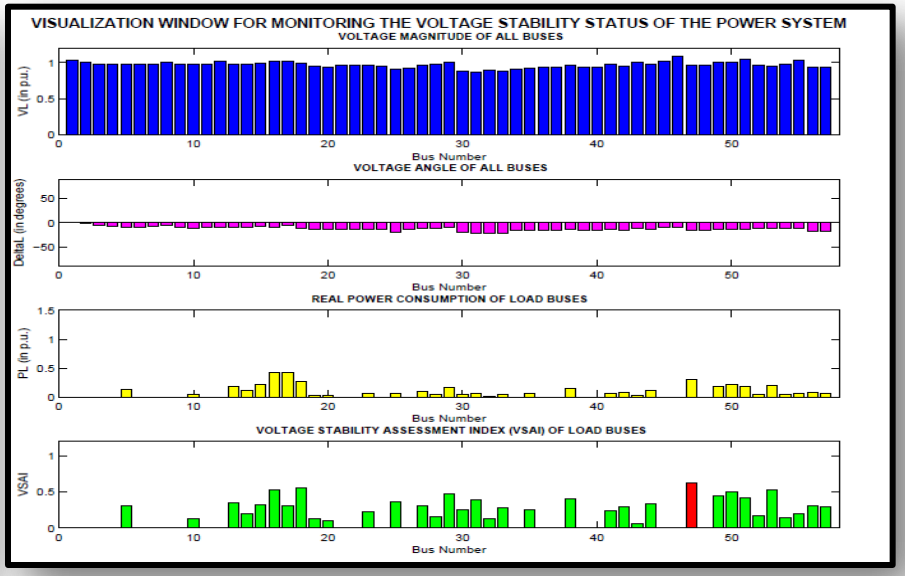
[B] Decrease in voltage stability due to contingencies (i.e. a type of large disturbance voltage stability problem) –

(3) Tripping of Line 46-47 & Line 50-51 in the IEEE-57 Bus test case:

Before Contingency



After 'N-2' Contingency



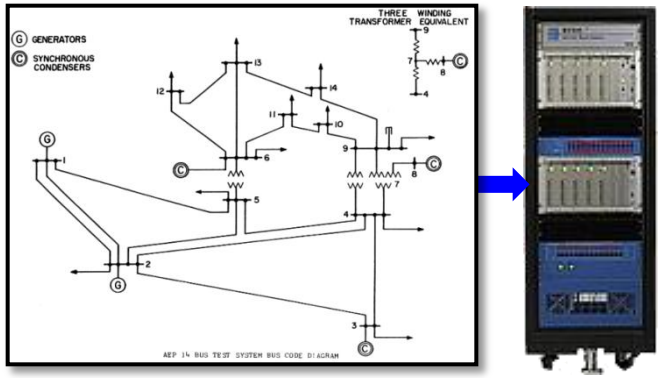
→ Increase in VSAI at the load bus 47 from 0.57 to 0.62 after the 1st contingency & from 0.62 to 0.64 after the 2nd contingency indicate successive decrease in voltage stability margin

→ CPF result also shows a reduction in λ-margin (indicating reduction in voltage stability margin) from 1.8921 to 1.7028 after the 1st contingency & from 1.7028 to 1.6152 after the 2nd contingency

5. Online Simulation Results

[A] Online Simulation of RT-VSM Tool using a Cyber-Physical Test Bed –

Physical Layer: RSCAD & RTDS with IEEE-14 Bus System

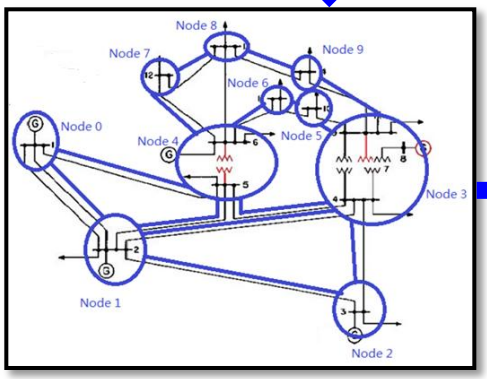


Sensor Layer: PMUs monitoring the IEEE-14 Bus System

Hardware PMU-1 (2 Modules)	Hardware PMU-2 (2 Modules)	Hardware PMU-3 (1 Module)	Hardware PMU-4 (1 Module)	Software PMU-1 (8 Modules)

Communication Layer: Splitting the IEEE-14 Bus System into Multiple Nodes

Hardware PDC-1
(for IP Address splitting of PMUs at the substations (nodes) in the IEEE-14-Bus System)



ns-3 NETWORK SIMULATOR

Real Time Application Layer: Real time voltage stability monitoring of IEEE-14 Bus System at Control Center Computer

Real Time Data Archival Layer: Archiving the real time measurements obtained from the IEEE-14 Bus System

Software PDC-1
(in Control Center Computer)

[B] Online Simulation Results of the RT-VSM Tool –

For the demo, please click on "Online Simulation Result Demo Video of RT-VSM Tool" embedded in the same webpage after this PDF document

For more details on the RT-VSM Tool, please contact:

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