Online Wide-Area Voltage Stability Monitoring and Control: RT-VSMAC Tool

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Outline

- Motivation for the RT-VSMAC Tool
- What is RT-VSMAC Tool?
- Unique Capabilities of the RT-VSMAC Tool
- Data Needs for the RT-VSMAC Tool
- Test Results
- Summary

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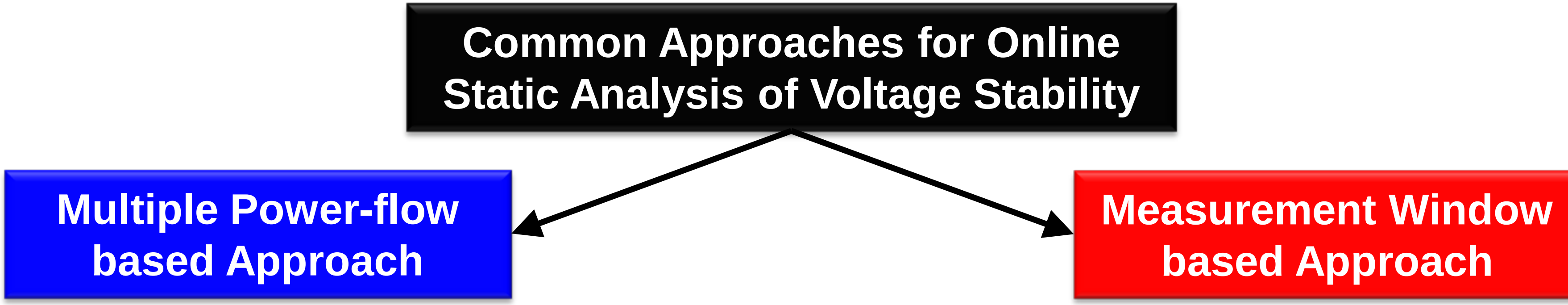
Motivation for a new real time 'monitoring module' of RT-VSMAC Tool –



(1) Limitation of 'Multiple Power-flow' based approaches –

(a) Computationally burdensome

(b) Not fast enough for real time applications

(2) Limitations of 'Measurement Window' based approaches –

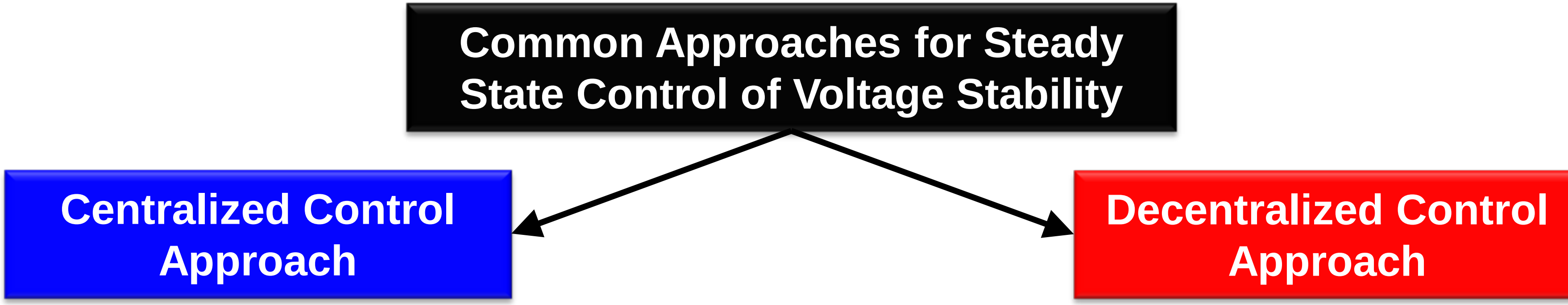
(a) Not accurate with the changing system states

(b) Following assumption may not be valid during the window period –

(i) Need the load side parameters to change, and

(ii) System side to remain constant

Motivation for a new real time ‘control module’ of RT-VSMAC Tool –



(1) Limitations of ‘Centralized’ approaches –

(a) Computationally burdensome

(b) Not fast enough for real time applications

(c) Control actions are highly dependent on mathematical models, which may lead to inaccuracy

(2) Limitations of ‘Decentralized or Local’ approaches –

(a) May not be accurate as they are based on local measurements only

(b) Wide area coordination of control devices not easy

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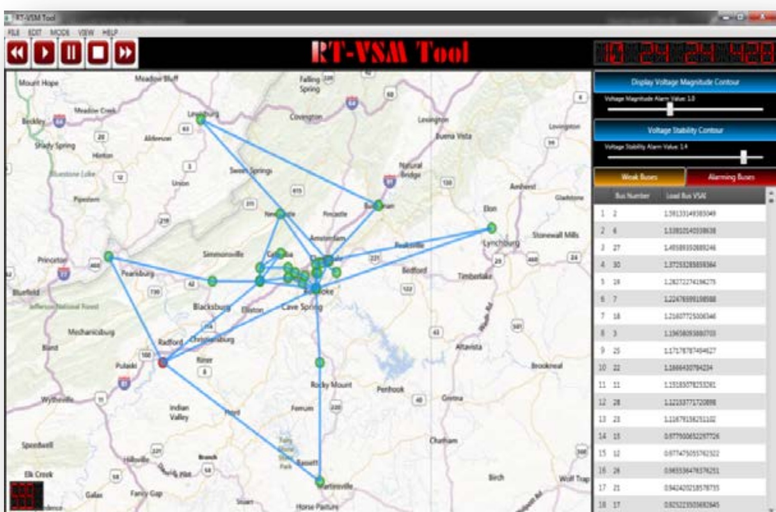
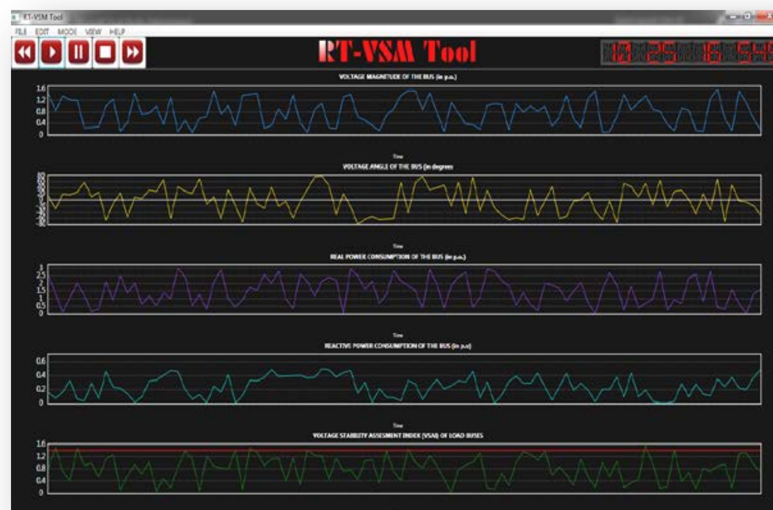
(1) It is a new tool for monitoring and controlling the voltage stability status of the power system

(2) Both the modules – ‘monitoring’ & ‘control’ use non-iterative mathematical analysis

(3) Monitoring module computes Voltage Stability Assessment Index (VSAI) and other critical metrics to indicate voltage stability status of the system

(4) Control module strategizes control actions based on VSAI values of load buses





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(1) The monitoring module computes the following –

→ "Easy-to-interpret" index for voltage stability status of the load buses.

VSAI near "0" indicates: Highly voltage stable

VSAI near "1" indicates: On the verge of voltage collapse

→ Voltage angle separation

→ Real and reactive power injections at all the buses

→ Real and reactive power flows in all the lines

(2) Provides a simple and yet comprehensive visualization of key metrics to the system operators

(3) Provides multiple dynamic alarm setting features to the system operators

(4) Based on the VSAI values, the control module strategizes the coordination of the assets according to their availability and real time status –

→ Transformer automatic load tap changer blocking at the selected buses

→ Local & Remote shunt reactive power compensation at the selected buses

→ Generator reactive power compensation at selected buses

→ Series reactive power compensation at selected lines

→ Local & Remote load-shedding at selected buses

(5) The control module has 2 sub-modules at the control action generation stage:

→ Control Action Activation Sub-module (CAAS) – Activates the previously strategized coordinated control actions in steps based on real time feedback from actual system measurements

→ Control Action Deactivation Sub-module (CADS) – Once, the CAAS has acted in steps to successfully enhance the voltage stability status at the targeted weak buses, the CADS deactivates the previously activated control actions in steps based on real time feedback from actual system measurements to ensure efficient use of system resources.

(6) Provides a simple and yet comprehensive visualization of the real time status of all the control devices (for voltage stability control) in the system to the system operators

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(1) Data requirements for ‘monitoring module’ –

→ Voltage phasors at the buses in the system

→ Topological information of the system, i.e. branch data

(2) Data requirements for ‘control module’ –

→ Status of the control devices (for voltage stability control) available in the system that include:

(a) Transformer automatic load tap changer blocking

(b) Shunt reactive power compensation devices

(c) Series reactive power compensation devices

(d) Generator reactive power and their limits

(e) Load priority for application of the load-shedding scheme

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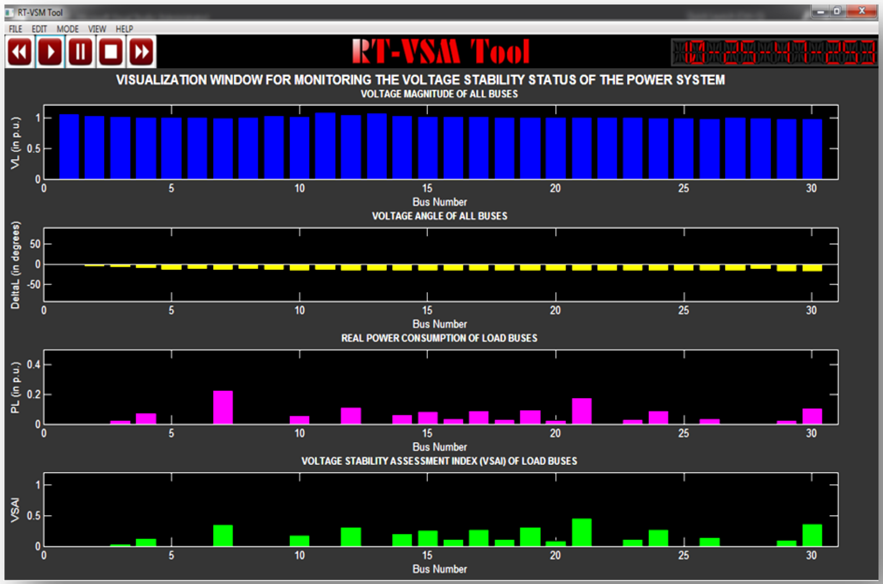
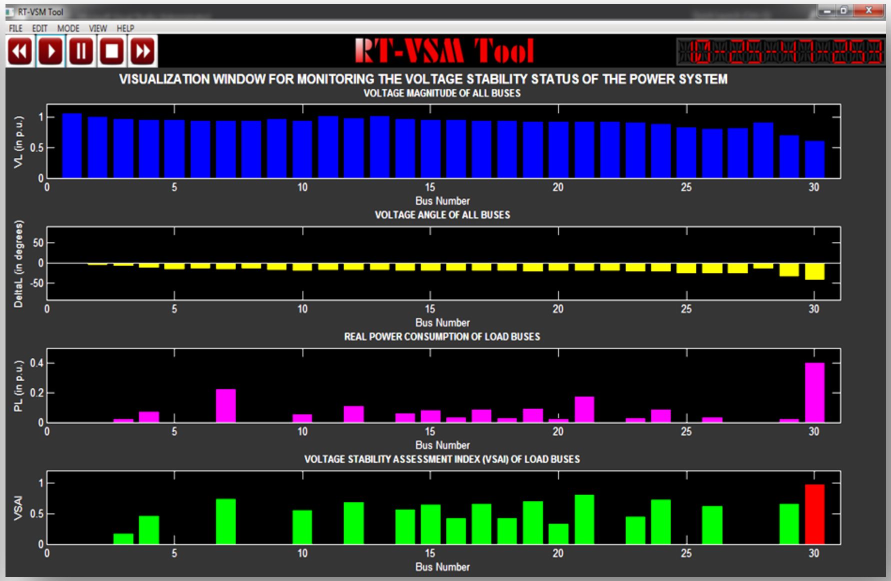
(1) Decrease in voltage stability due to increase in load (i.e. a type of small disturbance voltage stability issue) –

→ Increase in load at Bus-30 in the IEEE-30 Bus test case:

Base Case Loading



Stressed Case Loading

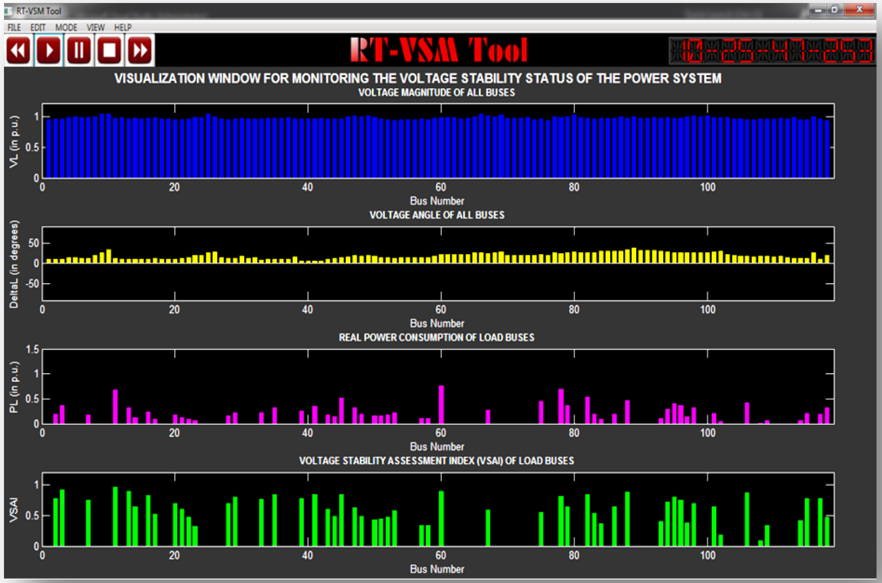


→ Increase in VSAI at the load buses indicate decrease in voltage stability

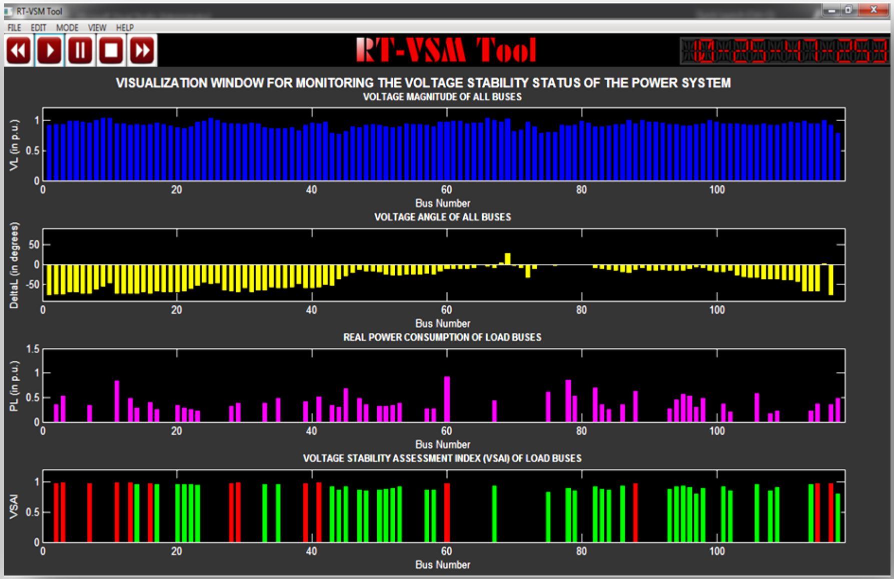
→ Power-flow fails to converge when the highest VSAI in the system is 0.985 (@ Bus-30)

→ Increase in load at all the load buses in the IEEE-118 Bus test case:

Base Case Loading



Stressed Case Loading



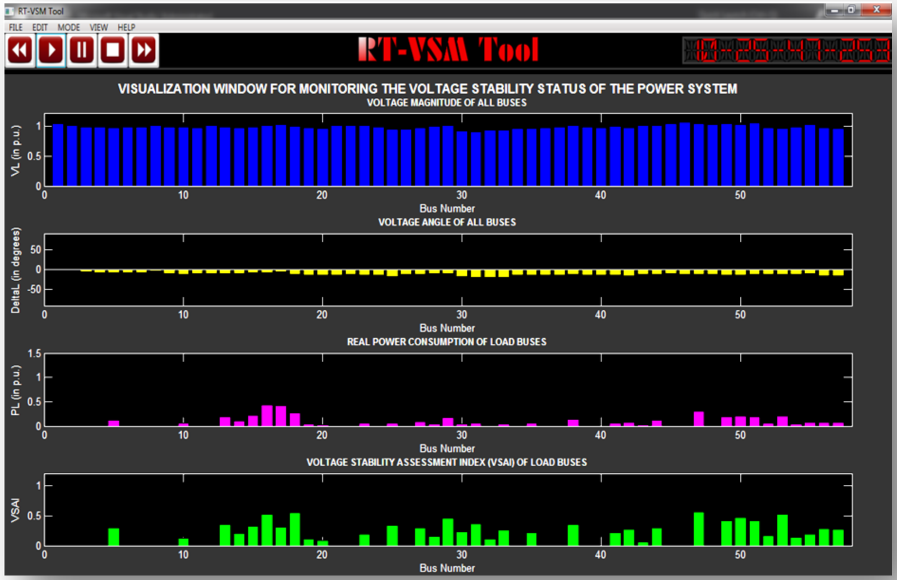
→ Increase in VSAI at the load buses indicate decrease in voltage stability

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

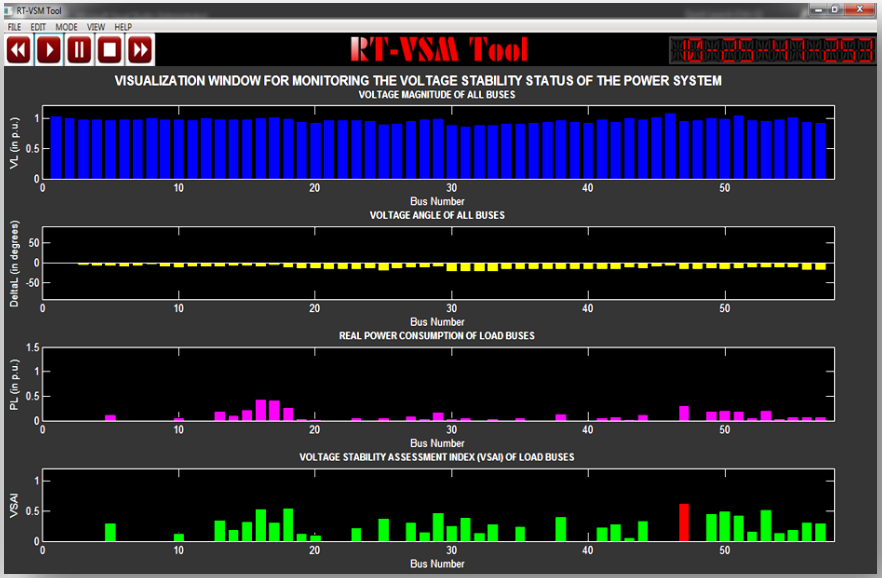
(2) Decrease in voltage stability due to contingency (i.e. a type of large disturbance voltage stability issue) –

→ Tripping of Line 46-47 in the IEEE-57 Bus test case:

Before Contingency



After Contingency



→ Increase in VSAI at the load bus 47 (from 0.57 to 0.62) indicate a slight decrease in voltage stability

→ Continuation Power-flow also shows a slight reduction in distance to point of collapse after the contingency

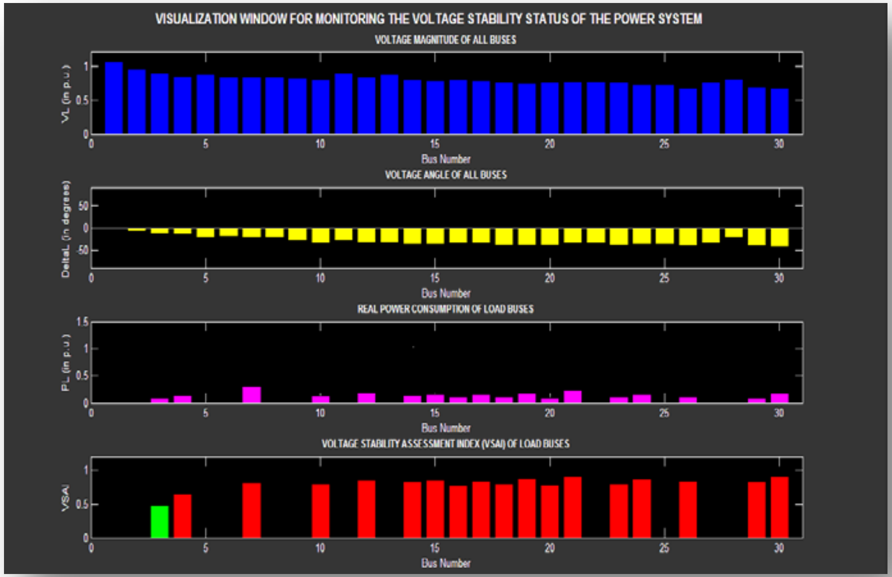
Voltage Stability Control

For the purpose of demonstration of voltage stability control module, following type of modifications have been made in the IEEE test cases –

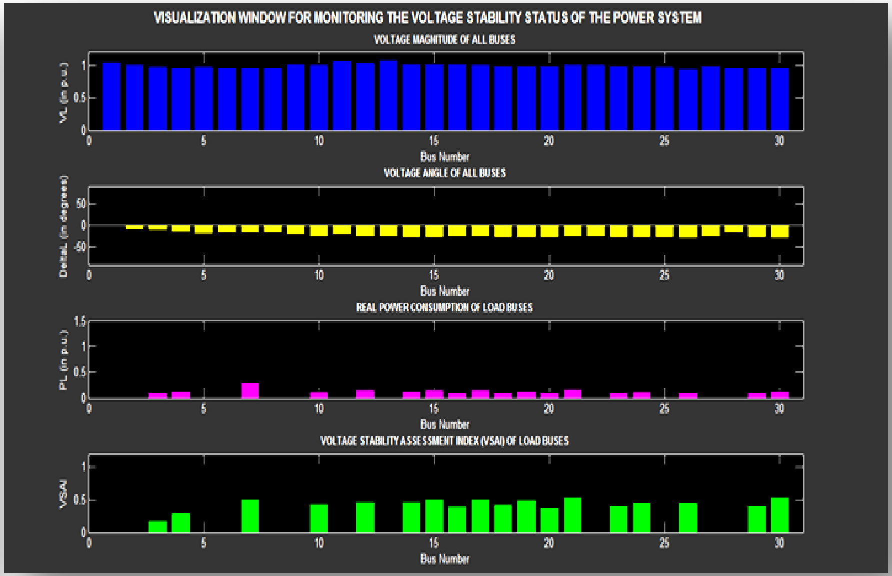
- → Including LTC Transformer at some of the load buses
- → Introduction of switched series capacitors in some of the lines connected to the load buses
- → Introduction of one or more switched shunt capacitor banks at some load buses

(1) IEEE-30 Bus test case: VSAI Alarm limit = 0.55

Pre-Control VSAI status



Post-Control VSAI Status



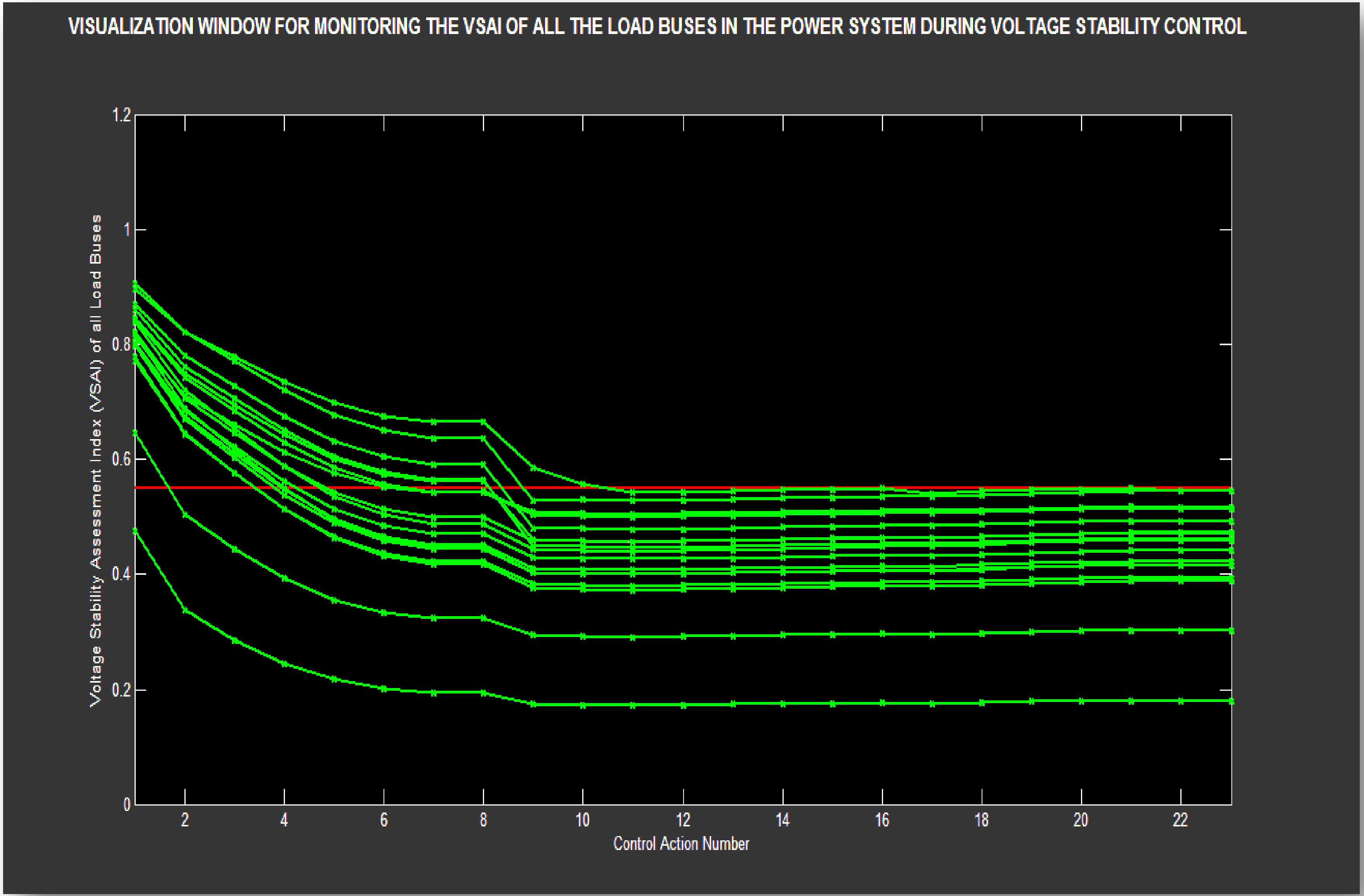
→ No. of load buses with VSAI above set alarm value before control: 17

→ No. of load buses with VSAI above set alarm value after control: 0

→ Weakest load bus VSAI before control: 0.9062

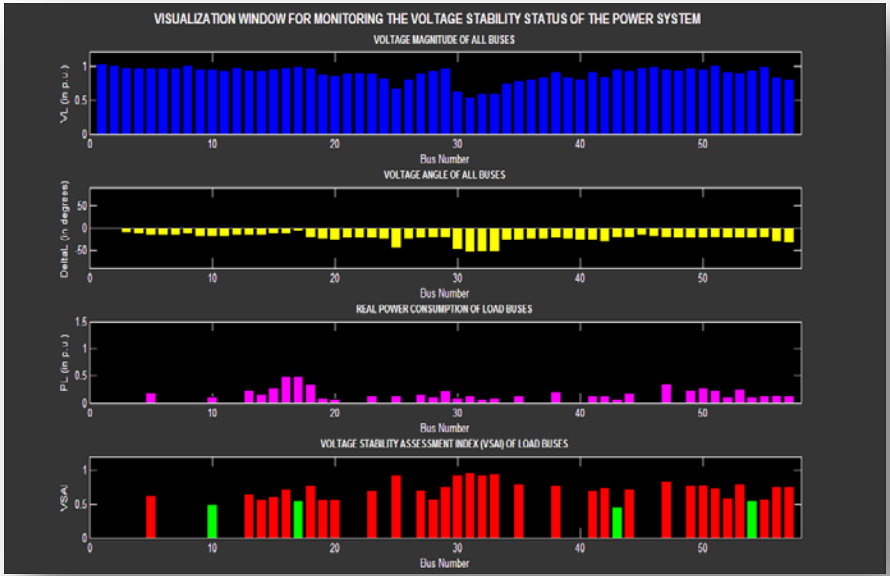
→ Weakest load bus VSAI after control: 0.5464

Stepped control stages in IEEE-30 Bus test case:

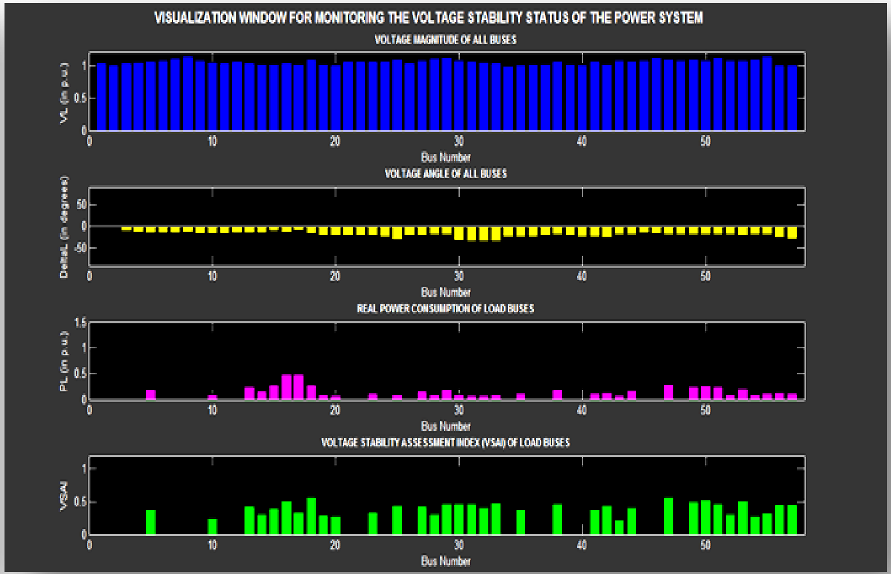


(2) IEEE-57 Bus test case: VSAI Alarm limit = 0.6

Pre-Control VSAI status



Post-Control VSAI Status



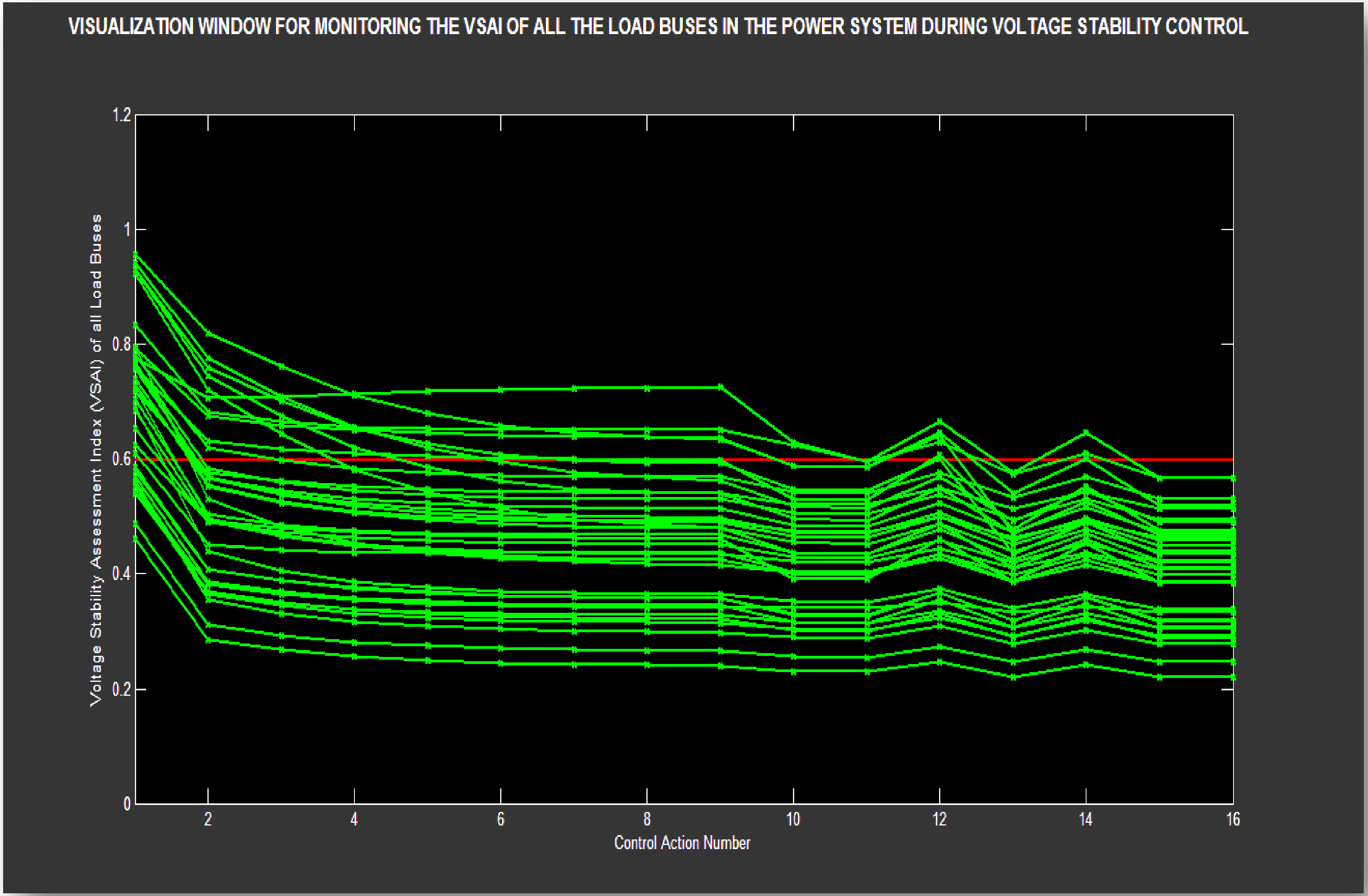
→ No. of load buses with VSAI above set alarm value before control: 25

→ No. of load buses with VSAI above set alarm value after control: 0

→ Weakest load bus VSAI before control: 0.9576

→ Weakest load bus VSAI after control: 0.5675

Stepped control stages in IEEE-57 Bus test case:



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(1) A new real time voltage stability monitoring and control tool ‘RT-VSMAC Tool’ has been developed

(2) The developed algorithm is non-iterative for monitoring as well as control

(3) Developed algorithms is comprehensive and simple

(4) Results of testing the monitoring module on different IEEE test cases have been discussed

(5) Results of testing the control module on different IEEE test cases have been presented

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