ECE 692 – Voltage Security Assessment Tool (VSAT) Tutorial and Case Study

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Introduction of VSAT

- 1- and 2-dimensional transfer limit search
- Contingency screening
- PV curve and VQ curve computation
- Modal analysis
- Remedial action identification
- Scalable distributed computation engine
Inputs and Outputs of VSAT

Important files

- Main Output Report
  - Scenario-ID.png
- Security Limit
  - Scenario-ID.txt
- PV Curve Output
  - Scenario-ID.csv
- VQ Curve Output
  - Scenario-ID.csv
- SPS Actions Report
  - Scenario-ID.csv
- Remedial Action Details
  - Scenario-ID.csv
- Contingency Screening Report
  - Scenario-ID.csv
- Remedial Action Main Output
  - Scenario-ID.csv
- Remedial Action Detail Control Report
  - Scenario-ID.csv
- Remedial Action Summary Report
  - Scenario-ID.csv
- User Requested Reports
  - Scenario-ID.csv
Security Assessment and Transfer Limit

• The Security Assessment Module determines:
  – Voltage security of a given base operating point
  – Security limits of one and two-dimensional power transfers (Range or Region of secure operation of the system)
Security Assessment and Transfer Limit

Input files

Parameter definition

Important!
Define the Transfer File
Define the Criteria File

Criteria File: C:\DSATools_13_re\Wsa\data\crit
Name: V/Q #1
Description:
7% voltage decline in area 1
12% Q reserve in each of zones 1, 4, 5, 6
10% Q reserve in zone 30
15 MVAR reserve in SVC

<table>
<thead>
<tr>
<th>No</th>
<th>Reserve Limit</th>
<th>Apply In</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12 %</td>
<td>Pre and post-contingency</td>
</tr>
<tr>
<td>2</td>
<td>12 %</td>
<td>Pre and post-contingency</td>
</tr>
<tr>
<td>3</td>
<td>12 %</td>
<td>Pre and post-contingency</td>
</tr>
<tr>
<td>4</td>
<td>12 %</td>
<td>Pre and post-contingency</td>
</tr>
<tr>
<td>5</td>
<td>10 %</td>
<td>Pre and post-contingency</td>
</tr>
<tr>
<td>6</td>
<td>15.0 MVAR</td>
<td>Pre and Post-Contingency</td>
</tr>
</tbody>
</table>

Composition of Group 6
- Include variable shunts of bus 2316
**Security Assessment and Transfer Limit**

![Diagram showing the relationship between load, source, and sink with the equation \( sz = sx + sy \).]

### Table: Security Assessment and Transfer Limit

<table>
<thead>
<tr>
<th>No</th>
<th>ID</th>
<th>Source(s)</th>
<th>Base Level MW</th>
<th>Target Increase MW</th>
<th>Target Decrease MW</th>
<th>Limit MW</th>
<th>Run</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>sx</td>
<td>EAST GEN</td>
<td>3500</td>
<td>600</td>
<td>500</td>
<td>4000</td>
<td>✓</td>
<td>Finished</td>
</tr>
<tr>
<td>2</td>
<td>sy</td>
<td>NORT GEN</td>
<td>2850</td>
<td>700</td>
<td>500</td>
<td>3250</td>
<td>✓</td>
<td>Finished</td>
</tr>
<tr>
<td>3</td>
<td>szy</td>
<td>EAST GEN</td>
<td>3500</td>
<td>800</td>
<td>500</td>
<td>7000</td>
<td>✓</td>
<td>Finished</td>
</tr>
<tr>
<td>4</td>
<td>sz</td>
<td>E-N GEN</td>
<td>6350</td>
<td>1600</td>
<td>500</td>
<td>7300</td>
<td>✓</td>
<td>Finished</td>
</tr>
</tbody>
</table>

### Range Scenarios

1. **sx**
   - Source: EAST GEN
   - Range: 3500 to 4200

2. **sy**
   - Source: NORT GEN
   - Range: 2500 to 3450

3. **sz**
   - Source: E-N GEN
   - Range: 6350 to 7350

### Contingency Table

<table>
<thead>
<tr>
<th>No</th>
<th>ID</th>
<th>Source X</th>
<th>Source D</th>
<th>Contingency</th>
<th>Limiting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>sx</td>
<td>4100</td>
<td>6268</td>
<td>CC42</td>
<td>Margin</td>
</tr>
<tr>
<td>2</td>
<td>sy</td>
<td>3356</td>
<td>6188</td>
<td>A 15</td>
<td>VAR Reserve</td>
</tr>
<tr>
<td>3</td>
<td>sz</td>
<td>7325</td>
<td>77205</td>
<td>A 19</td>
<td>VAR Reserve</td>
</tr>
</tbody>
</table>

--- Security Assessment completed successfully ---

sx: 6 sec

--- End ---
Secure Region Searching
Contingency Screening

- The method accounts for all non-linearities (i.e., not based on inaccurate linearized indices or interpolated trajectories).
- The method always accurately classifies the contingencies based on their true voltage stability margin.
- Screening is performed for specified power transfer.
Remedial Action

Remedial action option list

Preventive and corrective control
Define the Output Variables

Monitor

Monitor File: C:\DSATools_13_net\Vsat\datMon

Name: TestMon

Description: Monitor bus voltages, interface flows, and Criteria reactive reserves

Buses

pu Voltage of bus 7799
pu Voltage of bus 5512, 5511, 501
pu Voltage of bus 7798, 8207
pu Voltage of bus 201, 203, 1201, 101
Output Analysis
Case Study – IEEE 39-bus System

• Voltage collapse scenario: In TSAT, ramp the loads (1272.5 MW) in the orange box till voltage collapse happens. The maximum loadability is 1809.2 MW.

• Use VSAT to calculate the transfer limit:

Error = 3864.5 - 1809.2 = 2055.3 (MW)
Generator Capability Curves

• When True is specified, generator reactive power limits are computed from data specified in the Generator Capability file (in this case, a Generator Capability file must be provided).

• Generator capabilities are specified by piece-wise linear curves. Each generator may have several curves, each corresponding to one terminal voltage.
Generator Reactive Power Output in TSAT

• Define the generator capability curves according to the outputs of the three generator (31, 32 and 35) reactive power.
Results Comparison

• After enable the generator Var limits, the maximum loadability calculated by VSAT is **1814 MW**, which is close to **1809.2 MW** calculated by TSAT.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Insecure or Min/Max</th>
<th>Limiting</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>ID</td>
<td>Source X</td>
</tr>
<tr>
<td>1</td>
<td>IEEE39</td>
<td>5730</td>
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<tr>
<td>2</td>
<td>IEEE39</td>
<td>7781</td>
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</table>

Enable generator Var limits:

Disable generator Var limits:
Conclusion

• VSAT may provide optimistic or unrealistic estimation for the limits.
• Many parameters play critical roles in VSAT, so they need to be verified and given based on real system behaviors.
• In special situations in which time-domain simulations are required, such as when system dynamics and fast instability may be a concern, the Transient Security assessment Tool (TSAT) needs to be utilized.
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