Decision Tree Based Power System Dynamic Security Assessment

Group 7
Qingxin Shi, Xiao Kou
3.15.2016
## Constraints from previous groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Base Case</th>
<th>Constraints</th>
</tr>
</thead>
</table>
| 1     | 40GW      | $P_{G4} < 501.46$
|       |           | $P_{G65_2} > 994.13$ |
| 2     | 42.5GW    | $P_{G6} > 753.61$ |
| 3     | 45GW      | $P_{G6} < 764.39$ |
| 4     | 47.5GW    | $P_{G4} < 418.49$
|       |           | $P_{G9} < 1743.54$ |
| 5     | 50GW      | $P_{G4} < 336$ |
| 6     | 52.5GW    | $P_{G4} < 329.62$
|       |           | $P_{G9} < 1728.05$ |
# Case Scenarios

<table>
<thead>
<tr>
<th>Case</th>
<th>Load (GW)</th>
<th>Percentage Change (%)</th>
<th>Generation (GW)</th>
<th>Percentage Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53</td>
<td>-3.64</td>
<td>53.934</td>
<td>-3.67</td>
</tr>
<tr>
<td>2(Base)</td>
<td>55</td>
<td>0</td>
<td>55.991</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>56</td>
<td>1.82</td>
<td>57.022</td>
<td>1.84</td>
</tr>
<tr>
<td>4</td>
<td>57</td>
<td>3.64</td>
<td>58.055</td>
<td>3.69</td>
</tr>
</tbody>
</table>
## Generator Output Adjustments

<table>
<thead>
<tr>
<th>Generator</th>
<th>53</th>
<th>55 (Base Case)</th>
<th>56</th>
<th>57</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{G4}$</td>
<td>317.8</td>
<td>From 365.6 to 329.6</td>
<td>From 335.5 to 329.6</td>
<td>From 335.4 to 329.6</td>
</tr>
<tr>
<td>$P_{G6}$</td>
<td>From 737.3 to 753.6</td>
<td>From 831.7 to 764.6</td>
<td>From 778.4 to 764.6</td>
<td>From 778.0 to 764.6</td>
</tr>
<tr>
<td>$P_{G9}$</td>
<td>1666.3</td>
<td>From 1827.9 to 1728.0</td>
<td>From 1759.2 to 1728.0</td>
<td>From 1758.3 to 1728.0</td>
</tr>
<tr>
<td>$P_{G65_2}$</td>
<td>1311.0</td>
<td>1359.5</td>
<td>1384.1</td>
<td>1408.3</td>
</tr>
<tr>
<td>Case</td>
<td>No. of secure contingencies</td>
<td>No. of insecure contingencies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-----------------------------</td>
<td>-------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>323</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>315</td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>317</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>313</td>
<td>43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Power Angle and Voltage Response

Insecure case

Secure case

Contingency No. 340 356: 3P @ 114# - 113

Contingency No. 318 328: 3P@ 136# - 16
Decision tree – unpruned

Test option – Cross-validation with 10 folds.

Time taken to build model: 0.08 seconds

--- Stratified cross-validation ---

Correctly Classified Instances 1402
Incorrectly Classified Instances 22
Kappa statistic 0.9204
Mean absolute error 0.0164
Root mean squared error 0.1113
Relative absolute error 8.4084
Root relative squared error 36.6497
Coverage of cases (0.95 level) 99.2975
Mean rel. region size (0.95 level) 51.4747
Total Number of Instances 1424

--- Detailed Accuracy By Class ---

<table>
<thead>
<tr>
<th>Class</th>
<th>TP Rate</th>
<th>FP Rate</th>
<th>Precision</th>
<th>Recall</th>
<th>F-Measure</th>
<th>MCC</th>
<th>ROC Area</th>
<th>PRC Area</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>0.992</td>
<td>0.077</td>
<td>0.991</td>
<td>0.992</td>
<td>0.991</td>
<td>0.020</td>
<td>0.994</td>
<td>0.999</td>
<td>S</td>
</tr>
<tr>
<td>I</td>
<td>0.923</td>
<td>0.006</td>
<td>0.835</td>
<td>0.923</td>
<td>0.828</td>
<td>0.920</td>
<td>0.994</td>
<td>0.958</td>
<td>I</td>
</tr>
</tbody>
</table>

Weighted Avg.

|           | 0.985   | 0.069   | 0.984     | 0.985  | 0.985     | 0.923| 0.994    | 0.994    |

--- Confusion Matrix ---

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>1258</td>
<td>12</td>
</tr>
<tr>
<td>b</td>
<td>144</td>
<td>10</td>
</tr>
</tbody>
</table>

a = 5
b = I
Test option – Cross-validation with 10 folds.

Time taken to build model: 0.1 seconds

--- Stratified cross-validation ---
--- Summary ---

Correctly Classified Instances 1405 98.6667 %
Incorrectly Classified Instances 19 1.3333 %
Kappa statistic 0.9314
Mean absolute error 0.0186
Root mean squared error 0.109
Relative absolute error 9.5259 %
Root relative squared error 34.9059 %
Coverage of cases (0.95 level) 99.2978 %
Mean rel. region size (0.95 level) 51.861 %
Total Number of Instances 1424

--- Detailed Accuracy By Class ---

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</thead>
<tbody>
<tr>
<td>0.993</td>
<td>0.064</td>
<td>0.992</td>
<td>0.993</td>
<td>0.993</td>
<td>0.931</td>
<td>0.989</td>
<td>0.995</td>
<td>S</td>
</tr>
<tr>
<td>0.936</td>
<td>0.007</td>
<td>0.942</td>
<td>0.936</td>
<td>0.935</td>
<td>0.931</td>
<td>0.985</td>
<td>0.944</td>
<td>I</td>
</tr>
</tbody>
</table>

Weighted Avg. 0.987 0.058 0.987 0.987 0.987 0.987 0.987 0.989 0.992

--- Confusion Matrix ---

a = S

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>1269</td>
<td>16</td>
</tr>
<tr>
<td>b</td>
<td>146</td>
<td>146</td>
</tr>
</tbody>
</table>

Classification accuracy: 98.6667 %
Decision tree – unpruned

$P_{G11} \leq 1981.40$

$P_{G4} \leq 317.83$
Decision tree – pruned

$P_G \leq 317.83$
## Constraints Summary

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<td>$P_{G6}&gt;753.61$</td>
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<td>$P_{G6}&lt;764.39$</td>
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<td>52.5GW</td>
<td>$P_{G4}&lt;329.62$  $P_{G9}&lt;1728.05$</td>
</tr>
<tr>
<td>7</td>
<td>55GW</td>
<td>$P_{G4}&lt;317.83$  $P_{G11}&lt;1981.40$</td>
</tr>
</tbody>
</table>
Discussion on Voltage Violation

Why voltage setting of Gen. 162 is so low?

Sort bus voltage in ascending order

<table>
<thead>
<tr>
<th>Loading level (GW)</th>
<th>Bus 162</th>
<th>Bus 161</th>
<th>…</th>
<th>Bus 134</th>
<th>Bus 182</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of bus</td>
<td>Gen.</td>
<td>Load</td>
<td></td>
<td>Load</td>
<td>Gen.*</td>
</tr>
<tr>
<td>53</td>
<td>0.9138</td>
<td>0.9483</td>
<td></td>
<td>1.0983</td>
<td>1.1085</td>
</tr>
<tr>
<td>55</td>
<td>0.8931</td>
<td>0.9260</td>
<td></td>
<td>1.0995</td>
<td>1.1085</td>
</tr>
<tr>
<td>56</td>
<td>0.8812</td>
<td>0.9133</td>
<td></td>
<td>1.1002</td>
<td>1.1085</td>
</tr>
<tr>
<td>57</td>
<td>0.8693</td>
<td>0.9005</td>
<td></td>
<td>1.1009</td>
<td>1.1085</td>
</tr>
</tbody>
</table>

*Bus 182 is a synchronous phasor

Try to modify the Bus 162 voltage (55GW case):

<table>
<thead>
<tr>
<th>Cases</th>
<th>Power output</th>
<th>Bus voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bus 162</td>
<td>Bus 161</td>
</tr>
<tr>
<td>Before regulation</td>
<td>430MW + j115MVar</td>
<td>0.8931</td>
</tr>
<tr>
<td>After regulation</td>
<td>430MW + j150MVar</td>
<td>0.9576</td>
</tr>
</tbody>
</table>

Why voltage setting of Gen. 162 is so low?
Primary conclusion: the voltage violation does not affect whether a contingency is secure or not

<table>
<thead>
<tr>
<th>Case</th>
<th>No. of secure contingencies</th>
<th>No. of insecure contingencies (before regulation)</th>
<th>No. of insecure contingencies (after regulation)</th>
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</table>
Thank you for listening!

Special thanks to Yongli