Effect of Topology Control on System Reliability: TVA Test Case

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CIGRE, October 19-21, 2014

Outline

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- Contingency Analysis Tool with Corrective Topology Control
- Results
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- Conclusion
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Motivation, Industrial Practices, and Background

Motivation for Topology Control

- Control over transmission not fully utilized today
  - Transmission assets are treated as static in the short term
  - Transmission assets are traditionally modeled as assets that are not controllable

- However, operators may change transmission assets' states on an ad-hoc basis (in real-time)
  - Special Protection Schemes (SPS) in PJM
  - California ISO, congestion management procedures

Industrial Practices: PJM

- While such industrial practices exist today, these options are decided offline (**by prior observation / experience**)
- Need to integrate this flexibility within existing tools and management systems, e.g., **real-time contingency analysis (RTCA)**

http://www.pjm.com/markets-and-operations/etools/oasis/system-information/switching-solutions.aspx

Background: Corrective Topology Control

Post-contingency corrective transmission switching

- Shortly after a contingency, **switch** a line out of service **as a corrective action** (similar to bus-bar splitting)
- Implement **at most 1** corrective switching action
- But: identify multiple potential switching actions, in advance, per contingency to provide operators with choice

Contingency Analysis Tool with Corrective Topology Control

Contingency Analysis: Overview and Tool

- N-1: Line, Transformer, Generator
- Few seconds post-contingency (t_{+0})
  - Single snapshot of time
  - MVA compensation based on participation factors (various options are available)
  - Voltage control (PV set point) is fixed based on pre-contingency state (**except when Q_G violates Q_{MIN} or Q_{MAX} – then the PV set point is adjusted**)
- Tool development: multi-threaded high performance computing based real-time contingency analysis tool

Results

Tennessee Valley Authority (TVA) System

- 72 hours of data (PSS/E .RAW files)
- 1800 buses, 1700 transmission lines, 320 generators, 300 two-winding transformers, 100 three-winding transformers, and 180 switched shunts
- 1,800 contingencies per hour are simulated (non-radial transmission + generator contingencies)

Corrective Topology Control Benefits: Average Performance

- Ave flow violation reduction per contingency: **50%**
- Ave voltage violation reduction per contingency: **53%**
- Out of 5972 contingencies with violations, **17%** (1017) contingencies have no violation with corrective topology control
  - Corrective topology control fully removes **ALL VIOLATIONS** with a **SINGLE** transmission switching (post-contingency) solution
  - No new violations

PJM Test Case

- 167 PSS/E .RAW input files based on PJM data for testing (7 days)

- Network
  - ~15,000 buses; ~20,500 branches; ~2,700 gen; ~1,600 switchable shunts; ~8,900 contingencies

PJM Test Case Results

Tolerance: *V violation > 0.005 pu or MVA violation > 5MVA*

For single corrective switching actions:

- Number of contingencies with violations outside of tolerance: **4726**
  - (contingencies with violations that are evaluated)
- # of contingencies where there is **NO beneficial** corrective switching action:

10 cases: ~0.2%

PJM Test Case Results

- Ave flow viol. reduction per contingency: **81%**
- Ave voltage viol. reduction per contingency: **10%**
- Out of 4726 contingencies with violations, **52%** (2476) have no violation with corrective topology control (2nd best candidate corrective action: 43%)
- Corrective topology control fully removes **ALL VIOLATIONS** with a **SINGLE** transmission switching (post-contingency) solution (not considering tolerance)

Ongoing and Future Work

- Ongoing testing of the contingency analysis package at ISONE
  - Working with Dr. Eugene Litvinov, Dr. Slava Maslennikov, and Dr. Tongxin Zheng
- Ongoing collaboration with software vendors
  - **Update on our work to be presented at ABB's User Group meeting in Houston, TX on November 5, 2014**
- Stability analysis
- Bus bar splitting

Conclusions

- Demonstrated sizable benefits for two large-scale models (data provided by TVA, PJM; ongoing work with ISONE)
- Corrective topology control is a highly effective corrective action (with low costs) that can:
  - Manage congestion; improve deliverability of reserves
  - Reduce voltage violations and post-contingency line flow violations
- Developed open source RTCA with corrective topology control tool
- Proposed technology being evaluated by Alstom, ABB

Thank You!

Questions?

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Appendix: Background on Power Flow Tool

Corrective Topology Control: Tool Development

- Multi-threaded High Performance Computing base AC Power Flow Contingency Analysis Package with Corrective Topology Control
- Open Source
- Expanded IncSys' (Dr. Robin Podmore) Open Source AC Power Flow tool to create multi-threaded HPC real-time contingency analysis (RTCA) package

Modification to IncSys Tool

Java Tool Development

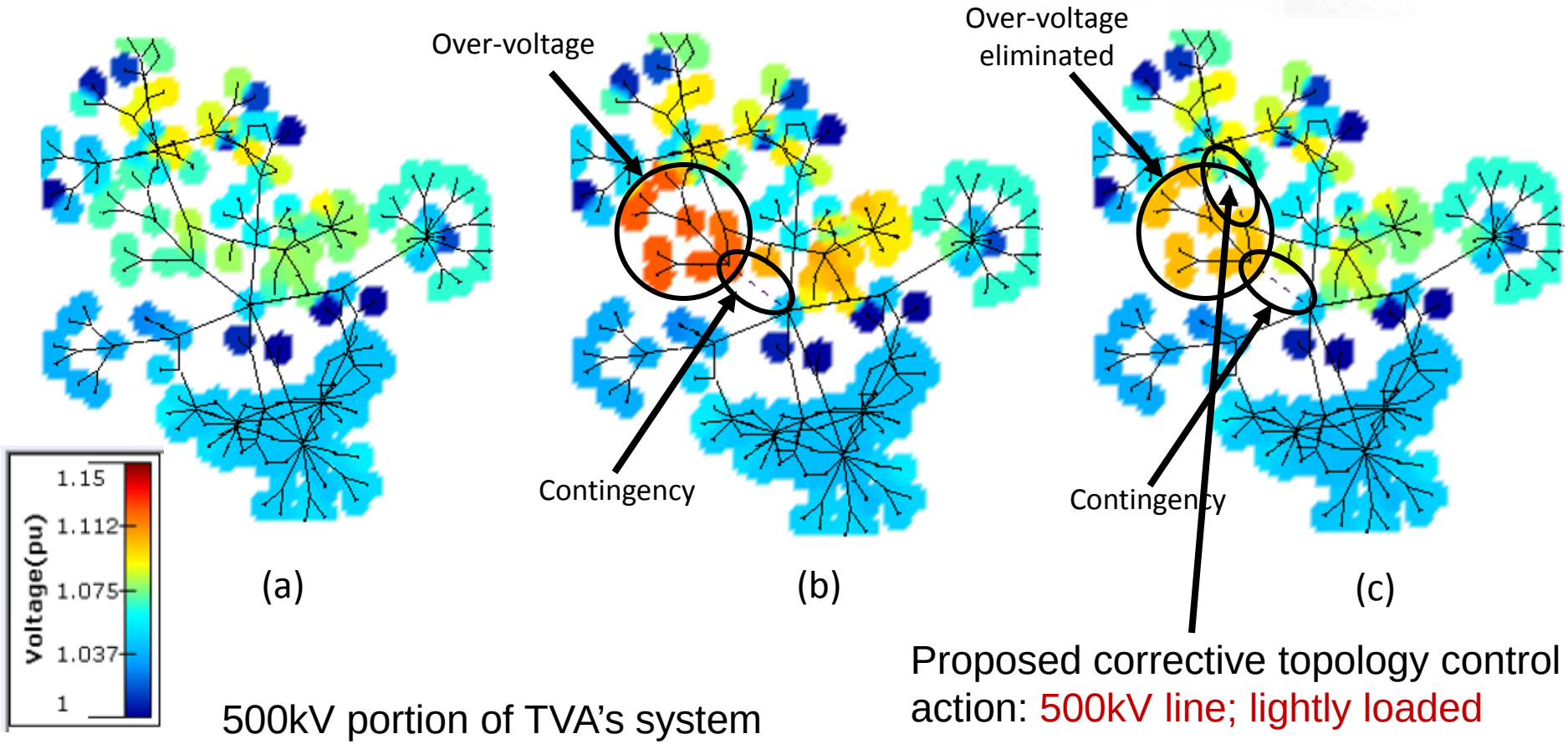
- Expanded OpenPA Open Source AC Power Flow tool
- Include Generator Var limit check in the tool
- Include Contingency Analysis (CA)
- Include Transmission Switching (TS)
- Integrate CA and TS program

AC Power Flow Tool

IncSys / PowerData Tool; open source Java based power flow tool features:

- Back-end data source - PSS/E raw file
- Fast-decoupled power flow
- Island detection
- Branch flow calculations
- Sparse B-matrix formulation, factorization, forward reduction and backward substitution

Specific Example: TVA



(a) pre-contingency, (b) post-contingency, and (c) post-contingency with corrective action

Motivation for Topology Control

- Model transmission assets as controllable (switchable) assets to:
  - Improve reliability
  - Manage congestion
  - Improve deliverability of reserves
  - Enhance management of intermittent renewable resources (via congestion management)
- Short-term reconfiguration of the transmission network (**temporarily** take transmission lines out of service)