NERC TPL-001:
“N-1-1” Contingency Analysis

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Portland Oregon
NERC Standard TPL-001-1

• Part of NERC Project 2006-02
  – Assess Transmission Future Needs and Develop Transmission Plans

• Would require Transmission Planners and Planning Coordinators to prepare an annual Planning Assessment of its portion of the Bulk Electric System

• Would require study and documentation of several classes of contingencies

• March 2010 ballot was not approved and will proceed to recirculation ballot
TPL-001-1 Event Categories

- P0: No Contingency, Normal System
- P1, P2: Single-Element Contingency
- P3: Generator Outage, followed by System Adjustments, followed by loss of another single element
- P4, P5: Multiple-Element Contingency
- P6: Transmission Outage, followed by System Adjustments, followed by loss of another single element
- P7: Multiple-Element Contingency (Common Structure)
Definitions

- **Base Case**: The power system in its normal steady-state, operation, with all elements in service that are expected to be in service.

- **Primary Contingency**: An loss of one or more system elements that occurs first. A Primary Contingency may be a planned or unplanned event.

- **Secondary Contingency**: An contingency that occurs after the Primary Contingency. This is usually an unplanned event.
System Adjustments

• TPL-001-1 allows “planned System adjustments such as Transmission configuration changes and re-dispatch of generation… if such adjustments are executable within the time duration applicable to the Facility Ratings”

• Interruption of Firm Transmission Service and Loss of Non-Consequential Load are allowed for some events

• System Adjustments are sometimes termed Remedial Action Schemes (RAS) or Special Protection Schemes (SPS)
Definitions

• **N-1-1 Contingency**: A sequence of events consisting of the initial loss of a single generator or transmission component (Primary Contingency), followed by system adjustments, followed by another loss of a single generator or transmission component (Secondary Contingency).

• **Model Criteria**: An evaluation of system conditions in Simulator, that if met, would cause a conditional system adjustment to occur.
“N-1-1” Contingencies

- TPL-001-1 category P3 and P6 outages could be classified “N-1-1” contingencies
  - A system element is forced out of service
  - Adjustments are made if necessary for security of the N-1 condition
  - A second system element is forced out of service
PowerWorld Simulator Contingency Modeling

• Many combinations of actions and elements, e.g.
  – Open a line
  – Change generator output
  – Partially curtail a load

• Unconditional or conditional actions, which occur only when specified system criteria are met

• Very detailed modeling of System Adjustments is possible
N-1-1 Analysis Process

Base Case

violations?
Yes
Fix violations

No

Run Primary Contingencies

violations?
Yes
Model System Adjustments

No

Traditional N-1 Analysis

Apply jth Primary Contingency

Run Secondary Contingencies

violations?
Yes
Model System Adjustments

No

For \(i = 1\) to number of Primary Contingencies
B7 Case: Normal System Operation

- One: 153 MW, AGC ON
- Two: 40 MW, 20 Mvar
- Three: 150 MW, 40 Mvar
- Four: 80 MW, 30 Mvar
- Five: 130 MW, 40 Mvar
- Six: 200 MW, 0 Mvar
- Seven: 200 MW, 0 Mvar
B7 Case: Primary Contingencies

- Without System Adjustments, case has several branch overloads during various Primary Contingencies
System Adjustments

• If effective System Adjustments are known, incorporate them into contingency definitions
• Simulator’s tools may be used to help design System Adjustments if they are not known:
  – Sensitivity Analysis
  – Line Loading Replicator
  – OPF: apply to post-contingent system when system adjustments are permitted post-contingency
  – SCOPF: apply to pre-contingent system when system adjustments are not permitted post-contingency
TLR Sensitivities: Single Element

• For contingencies with a single overload, solve contingency of interest
• Use TLR Sensitivities and Custom Expressions to estimate the impact of adjusting generators and loads in relieving the overload
TLR Sensitivities: Multiple Element

Source of Make-up Power

WTLR shows good locations to change load/generation
Line Loading Replicator

Overloaded line and estimated MW flow to meet MVA limit

Injection group containing all possible System Adjustment controls (gens and/or loads)

Suggested changes for achieving desired loading
OPF: System Adjustments After Contingency

- Primary Contingency: Loss of Line between buses 5 and 7
• Drop generator at bus 4, increase generator at bus 6
OPF Results: Difference Flows

Gen drop of 43 MW at bus 6 provides 30 MW relief on overloaded line
Modeling System Adjustments

- Contingency Block for Remedial Action Scheme
- Block may be applied to multiple contingencies that cause similar overloading on line 2-5
- Optionally assign Model Criteria to block elements or entire block to apply the RAS only at certain loading conditions
Primary Contingency with System Adjustments

Diagram showing various power lines and components with MW and Mvar ratings, along with AGC status (ON or OFF) and pu values.
Secondary Contingencies

- Solve a Primary Contingency and set as reference
- Run the contingency analysis on the set of Secondary Contingencies
- Repeat OPF or SCOPF processes for secondary contingencies that result in overloads

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SCOPF where System Adjustments are not Permitted After Contingency

- SCOPF difference case (relative to Base Case)
- Load must be shed at bus 5 for system to be secure for the secondary contingencies
System Adjustments Revised

- Revised RAS to apply to Primary Contingency so that Secondary Contingencies are secure with no further System Adjustments
Generator and Load Models

• Use OPF with Minimum Control Change objective function to assign uniform cost per MW to adjust any OPF control

• However, it may be desirable to assign a higher cost to load controls than to generation controls
  – In this way, load shedding may also be considered, but would only be applied if generator actions are ineffective or extreme
  – Use OPF with Minimum Cost objective function, and assign “V-shaped” marginal cost curves to generators and appropriate benefit curves to loads
Generator Cost Curve

- Slope of curve is “cost” to adjust generator output by 1 MW
- Set breakpoint to the current operating point
- Easy to implement with Auxiliary File

- **MW Break 1:** Set to Gen Min MW
- **MW Break 2:** Set to Gen MW (present output)
Generator Cost Curve Auxiliary File

• Cost to move all generators is set to $10 per MW

// assign all generators a cost of $10/MWh to deviate from their present outputs

SCRIPT
{
    SelectAll(GEN);
    SetData(GEN, [GenBidMW, GenBidMWhR, GenBidMW:1, GenBidMWhR:1],
            ["@GenMWMin", -10, "@GenMW", 10], Selected);
    UnSelectAll(GEN);
}

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Load Benefit Models

- Maximum load is set to nominal value
- Load benefit is much higher than cost to redispatch generation
Combining Two Lists of Contingencies

- Use “Join Active Contingencies” feature to combine list of primary and secondary contingencies into a complete N-1-1 set
More Information

• White paper and sample power flow case and contingencies