October 2009 10-Year Assessment
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Multiple Outage Analysis

In 2004, ATC began a multiple outage assessment with Commonwealth Associates (CAI) in order to perform more extensive analyses of our transmission system to identify NERC Category C type contingencies that could potentially lead to cascading. NERC Category C contingencies are specific sets of multiple outages including lines, transformers and generators.

ATC's intent is to review multiple outage impacts across its footprint at a minimum of once every five years. As part of the continuing NERC compliance process, we have enhanced our review in succeeding years. We revisited Category C contingency Analysis in 2005, 2006 and 2008. In 2006, additional Category C events were evaluated by screening Zone 3 (100-kV and above) facilities and ATC 345-kV transmission facilities in addition to the severe contingencies selected in 2005.

As part of our effort to continue to be aware of multiple outage impacts on our system, ATC performed additional Category C analyses and assessments in 2008 by screening Zone 5 (100-kV and above) facilities and a combination of ATC 345-kV facilities (including ATC 345/138-kV transformers) and generators (100 megawatts and above).

For the 2009 study, ATC used the 2014 and 2019 summer peak models with 95 percent Q_{max} including all projects identified in the 10-Year Assessment for additional steady state multiple outage analysis. Initial screening of the contingencies was done by using PTI's PSS/E software. Physical Operational Margin (POM) – Optimal Mitigation Measures (OPM) software was then used to determine available mitigation measures to alleviate violations that could potentially cause problems.

From the 2008 study, a set of 162 potentially critical Category C contingencies were selected for restudy in 2009. In addition to re-evaluation of previously defined multiple outages in 2009, we performed additional Category C analyses by screening all 345-kV branches and generators connected to ATC Bulk Electric System including all double ties into our service territory (100-kV and above). Furthermore, we performed NERC Category C bus section and breaker failure outages for our 100-kV and above system. Finally, we performed detailed multiple contingency analyses for the Zone 1 100-kV and above system branches and ATC generation connected to the Bulk Electric System including all double ties to Zone 1 (100-kV and above).

The total number of events tested in the initial screening using 2014 model was 28,876 which included:

- ❑ 105 potentially critical multiple outages, 98 of which were previously selected and tested in 2005, 2006 and 2008. Seven extra contingencies resulted from subsequent changes in system configuration.
- ❑ 23 multiple outages associated with 345-kV transmission facilities identified in 2006 as severe contingencies.
- ❑ 28 multiple outages associated with Zone 3 which were identified as severe in 2006.
- ❑ Six multiple outages from Zone 5 identified during 2008 study as severe.
- ❑ 31 Category C section outages from an existing ATC list for 100-kV and above.
- ❑ 104 Category C breaker failure outages from an existing ATC list for ATC 100-kV and above.

- 18,657 multiple outages associated with:
  - all ATC 345-kV branches and generators connected to the Bulk Electric System, and
  - all double ties to ATC (100-kV and above).
- 9,922 multiple outages associated with Zone 1 comprising of a combination of all branches plus ties (100-kV and above), and ATC generators connected to the Bulk Electric System.

Out of the 28,876 events analyzed, 343 events caused system limitations (both thermal and voltage limitations plus unsolved cases). Physical Operational Margin (POM) – Optimal Mitigation Measure (OPM) software was used to mitigate the resulting system problems. Of the 343 contingencies, 11 contingencies were found to be invalid, 297 were mitigated fully without load shedding through generation re-dispatch, capacitor bank adjustment, under load tap changing and/or phase shifter adjustment. 35 contingencies required load shedding to mitigate in addition to other remedial actions. As we did in 2008, we found that cascading could be ruled out for Category C contingencies on our 2014 system through the use of generation redispatch and load shedding. Ranked based on the amount of load shedding, the top 5 category C events for the 2014 system are:

- Fitzgerald 345/138-kV T1 and Wooden Shoe - Neevin 138-kV line #1
- Hoover - Arnott 138-kV line #1 and White Lake - Waupaca 138-kV Line #1
- Rocky Run 345/115-kV T1 and Rocky Run 345/115-kV transformer #2
- Whiting Avenue - Hoover 115-kV line #1 and Harrison - Waupaca 138-kV line #1, and
- White Lake 1 - Waupaca 138-kV line #1 and Whiting Avenue - Hoover 115-kV line #1.

To reassess the long-term planning horizon, the 35 Category C events resulting in load shedding to mitigate potential system problems in 2014 were repeated using the 2019 summer peak model including all projects identified in the 2009 10-Year Assessment.

Of the 35 events analyzed, one event caused no system violations while 34 events had potential system problems in 2019. Twenty nine of the 35 events resulted in system problems that were potentially more severe in 2019 than in 2014.

Following are the 29 Category C contingencies that worsened in 2019 and the additional load that needed to be shed compared to 2014:

Category C contingency	*MW load shed in 2014*	*MW load shed in 2019*	*Difference in MW*
M-38 - NORTH LAKE 138-kV LINE #1 AND M-38 - PERCH LAKE 138-kV LINE #1	54.42	84.13	29.71
FITZGERALD 345/138-kV T1 AND WOODEN SHOE - NEEVIN 138-kV LINE #1	126.00	158.00	32.00
WERNER - WHITE LAKE 138-kV LINE #1 AND WHITNG AV- ROCKY RUN 115-kV LINE #1	5.60	16.90	11.30
MAINE -PINE 115-kV LINE #1 AND GARDNER PARK - BLACK BROOK 115-kV LINE #1	27.20	67.20	40.00
MAINE - PINE 115-kV LINE #1 AND KELLY - BUNKER HILL 115-kV LINE #1	24.10	65.30	41.20
ARPIN 345/138-kV T1 AND BAKER W - COYNE 115-kV LINE #1	1.00	87.90	86.90
MAINE - HILLTOP 115-kV AND GARDNER PARK - BLACK BROOK 115-kV LINE #1	3.20	12.80	9.60
SARATOGA 138/115-kV T1 AND SIGEL 138 - ARPIN 138-kV LINE #1	1.20	24.30	23.10
SIGEL - ARPIN 138-kV LINE #1 AND BAKER W - SARATOGA 115-kV LINE #1	1.20	21.50	20.30
ROCKY RUN 345/115-kV T1 AND ROCKY RUN 345/115-kV T2	64.70	95.20	30.50
ROCKY RUN 345/115-kV T1 AND ROCKY RUN 345/115-kV T3	4.20	38.60	34.40
ROCKY RUN 345/115-kV T2 AND ROCKY RUN 345/115-kV T3	35.00	69.60	34.60
HOOVER 138/115-kV AND HARRISON - WAUPACA 138-kV LINE #1	4.20	24.90	20.70
HOOVER – ARNOTT 138-kV LINE #1 AND HARRISON – WAUPACA 138-kV LINE #1	7.60	37.20	29.60
SUMMIT LAKE - VENUS 115-kV LINE #1 AND ANTIGO - BLACK BROOK 115-kV LINE #1	15.94	16.92	0.98
MAINE - PINE 115-kV LINE #1 AND BUNKER HILL - PINE 115-kV LINE #1	20.80	137.50	116.70
HOLYWOOD - SARATOGA 138-kV LINE #1 AND BAKER W - COYNE 115-kV LINE #1	19.60	39.90	20.30
HOLYWOOD - PORT EDWARDS 138-kV LINE #1 AND BAKER W - COYNE 115-kV LINE #1	23.00	46.50	23.50
HOOVER 138/115-kV T1 AND WHITE LAKE - WAUPACA 138-kV LINE #1	59.30	122.60	63.30

Category C contingency	*MW load shed in 2014*	*MW load shed in 2019*	*Difference in MW*
HOOVER - ARNOTT 138-kV LINE #1 AND WHITE LAKE - WAUPACA 138-kV LINE #1	77.20	96.98	19.78
SIGEL - ARPIN 138-kV LINE #1 AND BAKER W - COYNE 115-kV LINE #1	33.10	117.30	84.20
WHITE LAKE 1 - WAUPACA 138-kV LINE #1 AND WHITING AV – HOOVER 115-kV LINE #1	64.33	75.87	11.54
WHITE LAKE - WAUPACA 138-kV LINE #1 AND GOLDEN SANDS - ARNOTT 138-kV LINE #1	7.60	36.30	28.70
WHITNG AV- HOOVER 115-kV LINE #1 AND GOLDEN SANDS-HARTMAN CREEK 138-kV LINE #1	29.77	31.60	1.83
WHITING AV - HOOVER 115-kV LINE #1 AND HARRISON – WAUPACA 138-kV LINE #1	64.50	103.58	39.08
WHITING AV- HOOVER 115-kV LINE #1 AND HARRISON – HARTMAN CREEK 138-kV LINE #1	29.77	55.00	25.23
M-38 138-kV BUS BREAKER FAILURE	54.42	55.46	1.04
STRAITS 138-kV BUS BREAKER FAILURE	60.50	130.50	70.00
ROCKY RUN 115-kV BUS BREAKER FAILURE	59.80	97.90	38.10

Although it is estimated that cascading could be ruled out for Category C contingencies on our 2014 and 2019 systems through the use of specific load shedding and generation redispatch, study results are subject to further review by ATC Planning and System Operations to develop or confirm appropriate and more specific operating procedures.