Commonwealth Associates, Inc.

Commonwealth
associates, inc.

Who We Are

- We are a consulting engineering firm that specializes in the services related to the transmission and use of electrical energy.
- We have offices in Michigan, Washington and Atlanta.
- We are employee owned and managed.

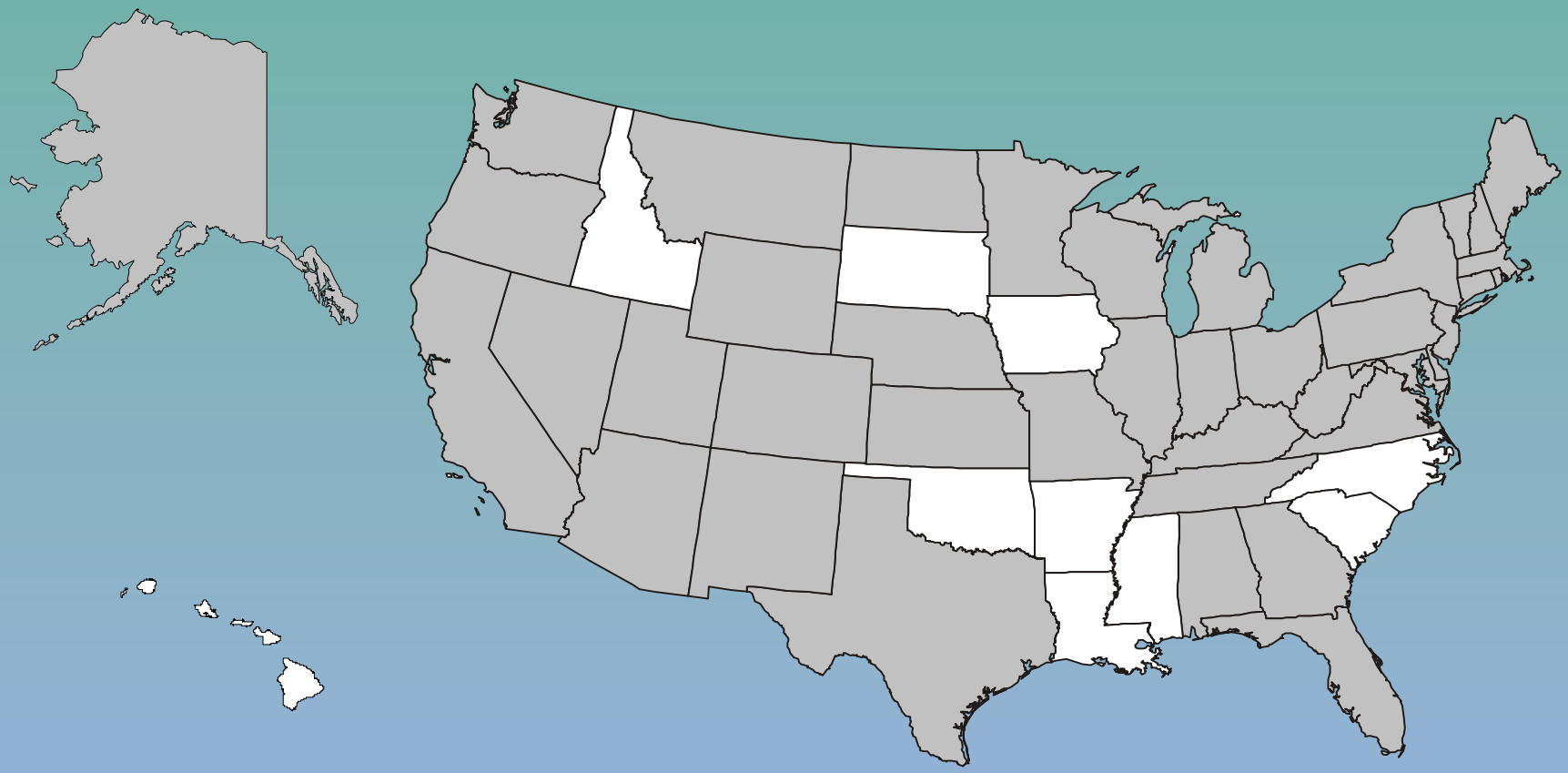
Commonwealth associates, inc.

Who We Are

- We are a consulting engineering firm that specializes in the services related to the transmission and use of electrical energy.
- We have offices in Michigan, Washington, and Atlanta.
- We are employee owned and managed.

Commonwealth associates, inc.

Project Locations – Last 5 Years



States with Projects

States without Projects

Commonwealth associates, inc.

System Studies and TRANSMISSION 2000

Commonwealth associates, inc.

Services

- Electrical Studies
- Electrical Engineering Support to Transmission Department
- Electrical Engineering Support to Substation Department
- TRANSMISSION 2000® and Customized Computer Programming

Commonwealth associates, inc.

Electric Grid Cascading Outage Analysis

- A verifiable and complete list of “breaker-to-breaker” contingencies
- Identification of ALL contingencies that cause violations and a direct or indirect assessment of all double (Category B and C) contingency combinations
- An analytical methodology to supplement your engineer’s experience and judgment

Commonwealth associates, inc.

Electric Grid Cascading Outage Analysis

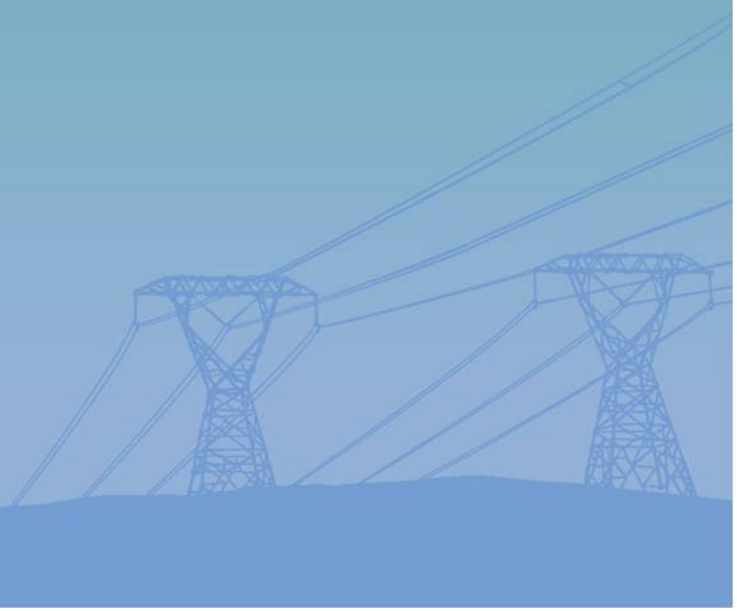
Provides an objective, repeatable, and reasonable classification of contingencies:

- those that will not cause outages beyond a predetermined area
- those that cannot be eliminated as potential causes for widespread outages

Commonwealth associates, inc.

Electric Grid Cascading Outage Analysis

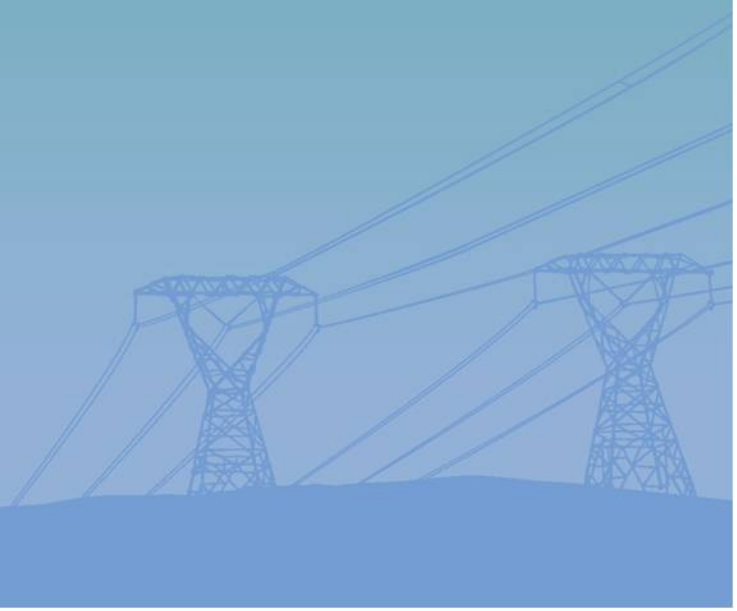
Provides a priority list of trouble facilities that identifies and suggests root causes for contingencies that may initiate widespread outages



Commonwealth associates, inc.

Electric Grid Cascading Outage Analysis

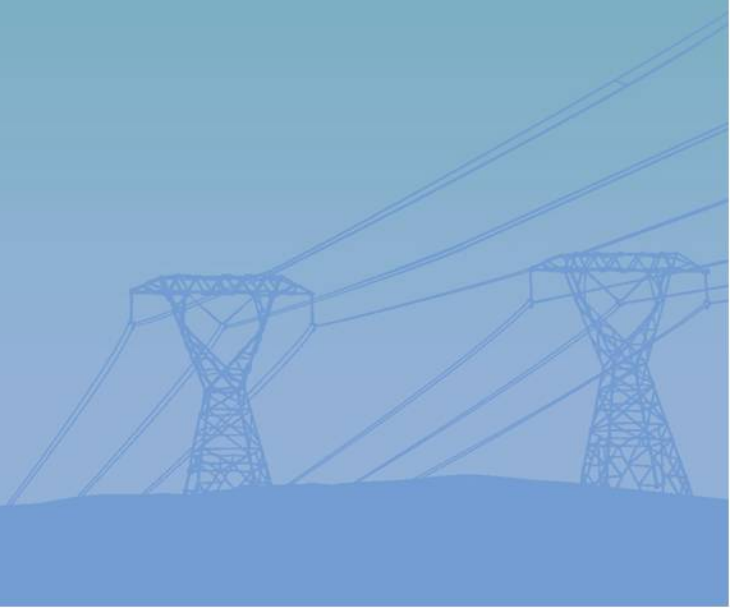
Provides an independent evaluation of your system suitable for use as compliance documentation that management can include in their “due diligence” reporting



Commonwealth associates, inc.

Data Requirements

- Minimum
  - Power flow case in standard format (PSS/E or GE)
- Additional Data
  - Contingency Lists (*.con, *.mon, and *.sub files)
  - FERC Form 715 One-Line or Switching Diagrams



Commonwealth associates, inc.

Contingency Identification

Contingencies can be:

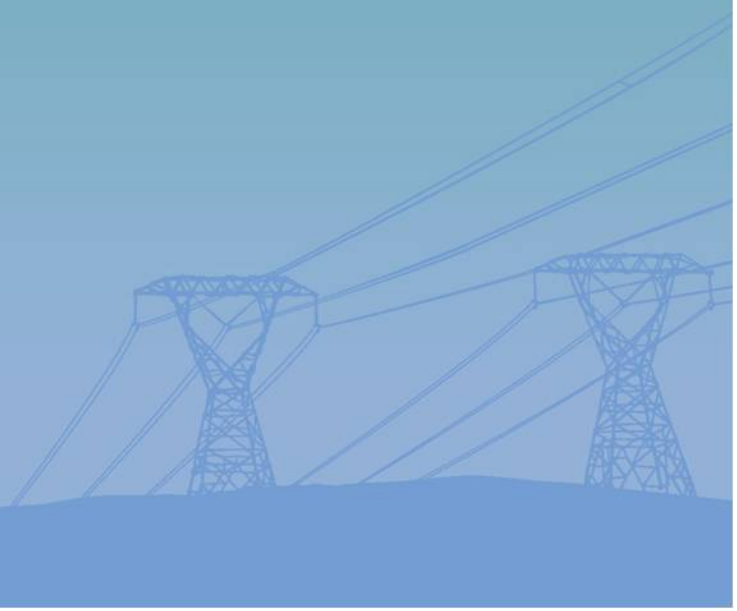
- Provided by you
- Generated for Power Flow Data
- Breaker to Breaker Contingencies from One-Line or Switching Diagrams

* Process is most effective with a “good” set of base contingencies

Commonwealth associates, inc.

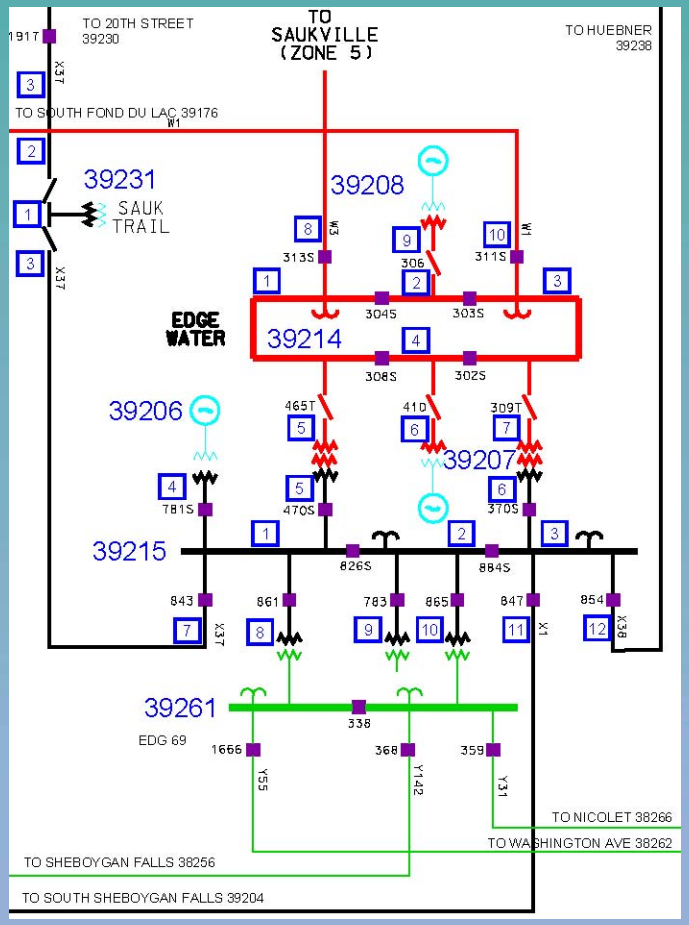
NERC Category C Contingencies

- Combinations of NERC Category B Contingencies (Double Contingencies)
- Bus Section Contingencies
- Breaker Failure Contingencies



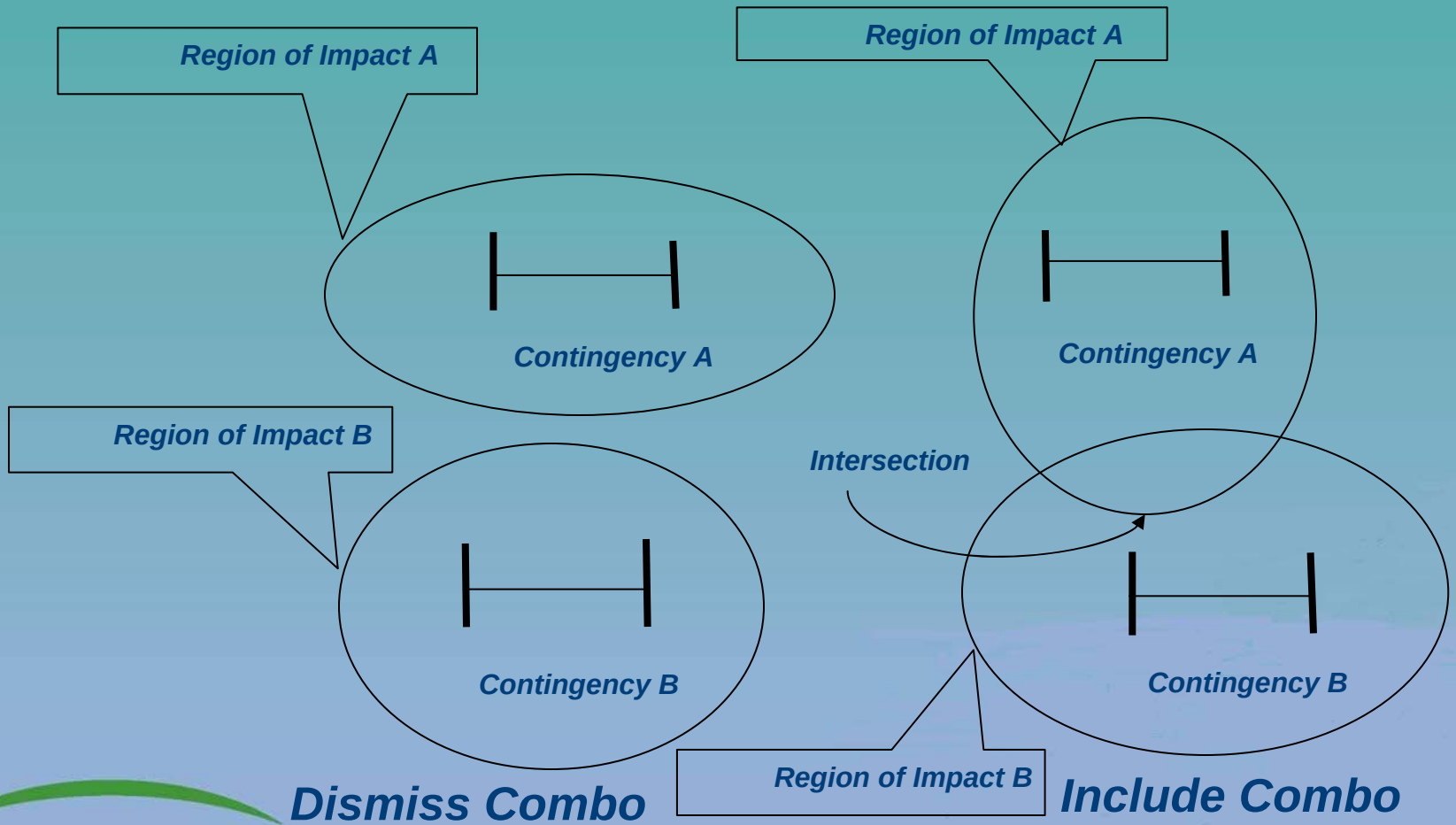
Commonwealth associates, inc.

Bus Section and Breaker Failure Contingencies



Commonwealth associates, inc.

Combinations of Category B Contingencies



Commonwealth associates, inc.

Objective Criteria for Discounting Vulnerability to Widespread Outages

Base Assumption

If a system does not have violations, it is secure and will not cascade. If rating violations exist, the transmission element may fail.

Methodology

Simulate the system under quasi-steady state operation until there aren't any applicable rating violations

Verification

Process is verifiable by following outage sequences with any standard power flow

Commonwealth associates, inc.

Objective Criteria for Discounting Vulnerability to Widespread Outages

- No applicable rating violations
- Load drop less then specified amount (we use 500 MW)
- Power flow solves
  - Load drop to eliminate unsolved cases
  - Interrupted power flow is a violation until solved

Commonwealth associates, inc.

Identifying Significant Contingencies

- Load Drop Index – total amount of load dropped by every combination that includes that Category B contingency
- Violation Index – number of violation-causing combinations each Category B contingency participates in
- Can we preclude cascading?

Commonwealth associates, inc.

Reliability Compliance Report

- Provide an independent engineer's evaluation of your system for compliance with NERC Category C requirements
- Identify those Category C contingencies that cannot be ruled out as possible initiating events to cascading outages
- Document your due diligence in completing a Category C analysis
- Provide focus on potential problems in your system that may need to be addressed

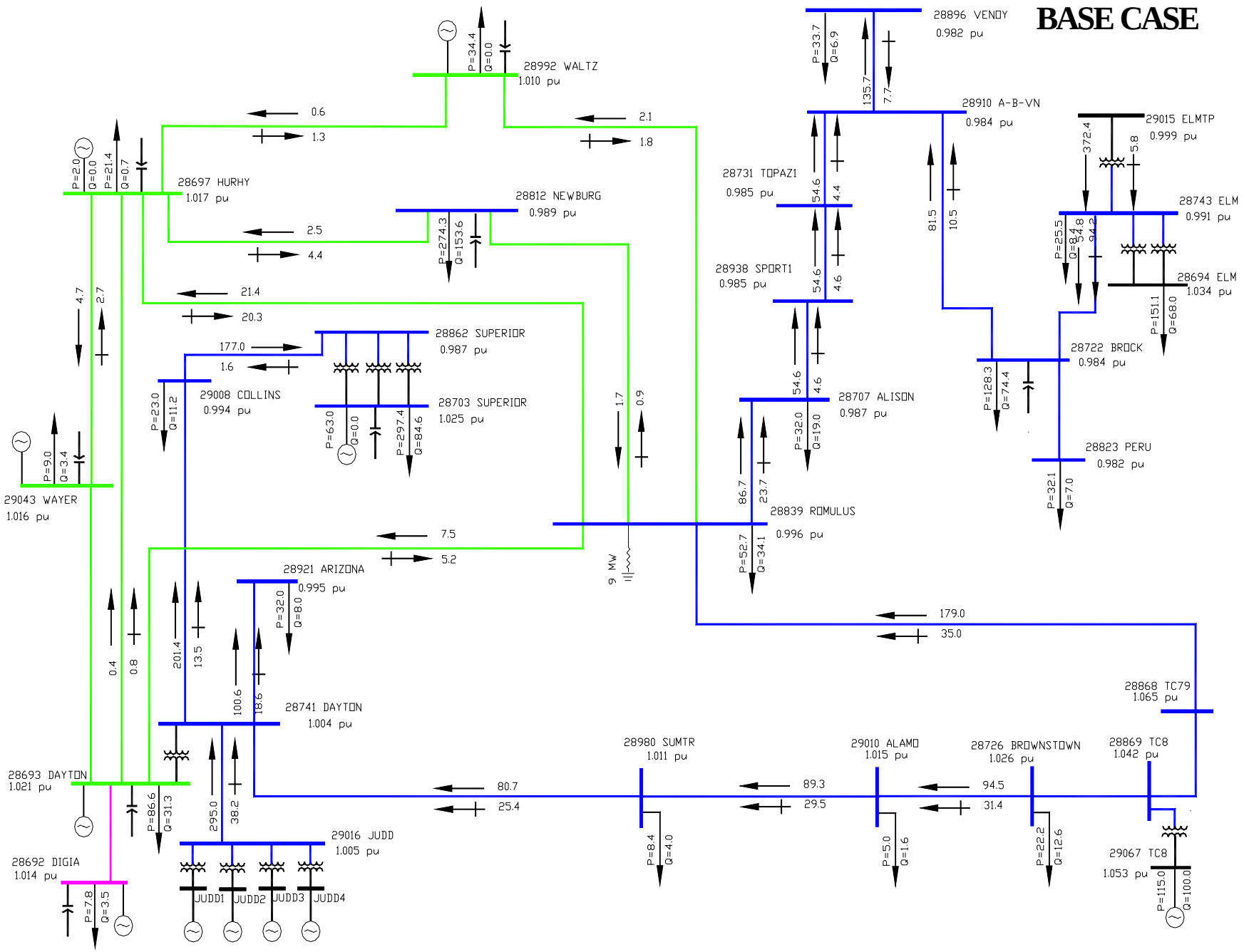
Commonwealth associates, inc.

Example of Category C Contingency that we can preclude as a likely cause for Widespread Outages

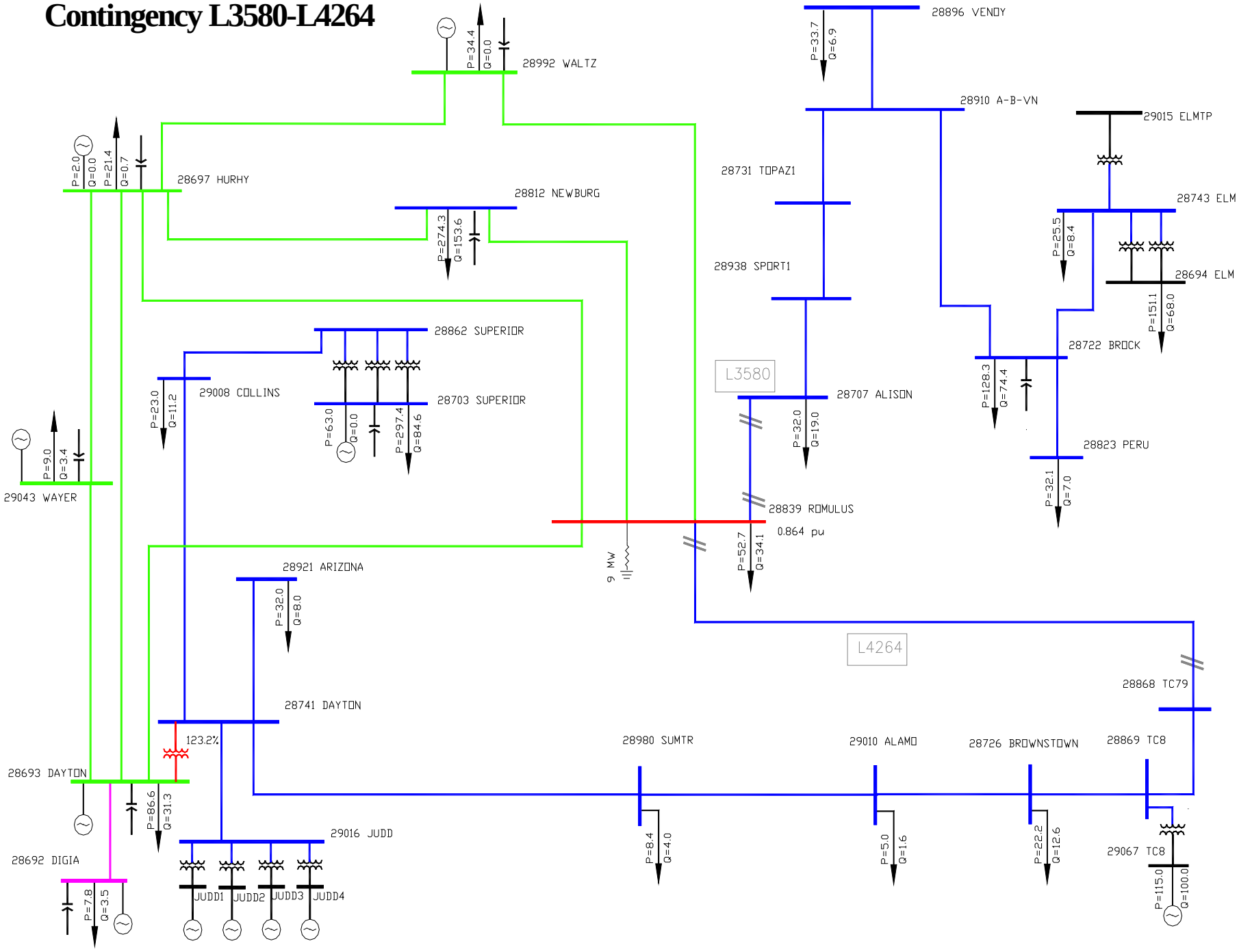
- Romulus to Trenton Channel (L4264)
  Romulus to Alison (L3580) 120 kV Lines
- Loss of Dayton 120/40 kV Transformer (28741-28693-1)
- Four steps of load drop to solve
- 156 MW load drop
- Outline for operating procedure

Commonwealth associates, inc.

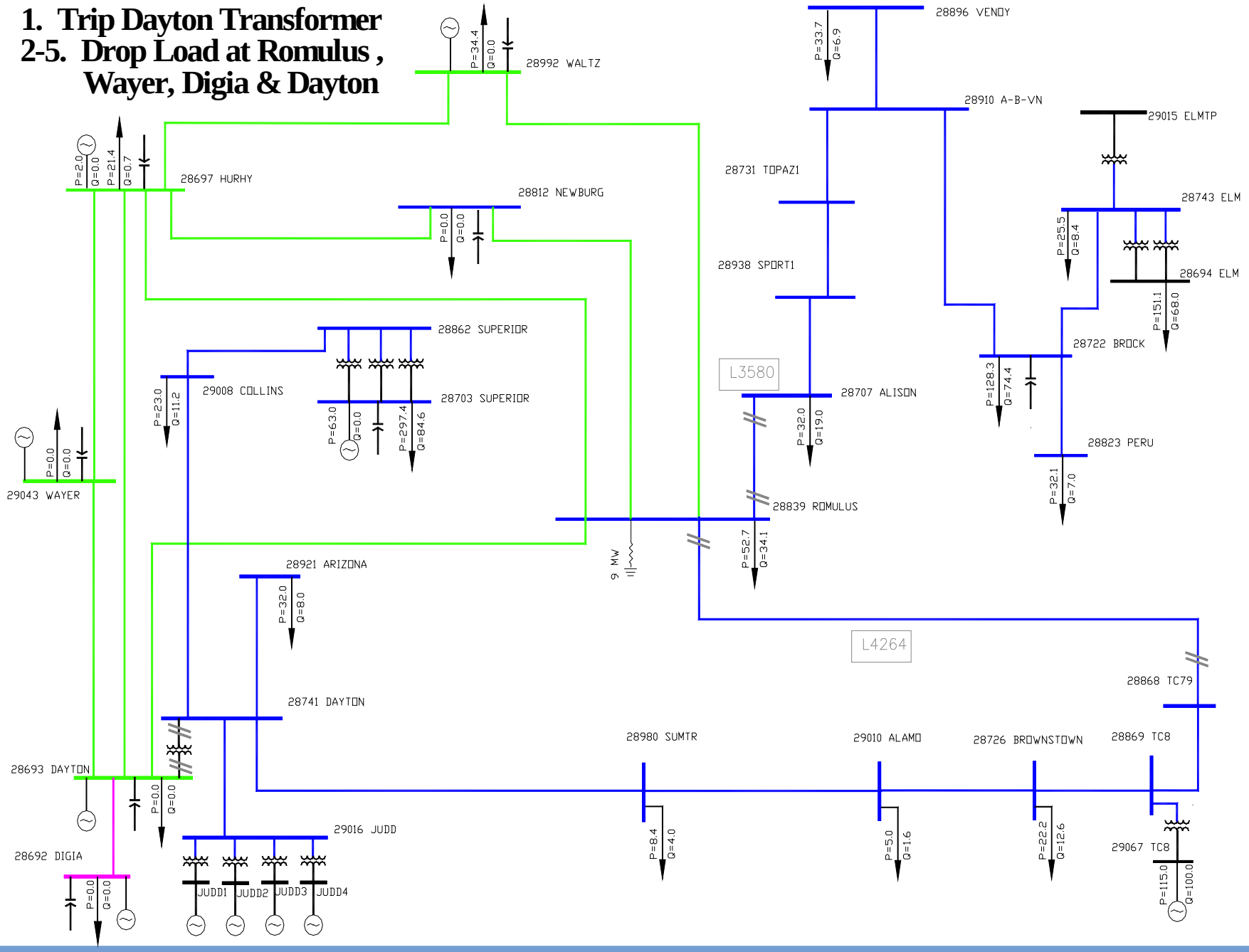
BASE CASE


28992 WALTZ
1.010 pu
P=34.4
Q=0.0
0.6
1.3
2.1
1.8
28697 HURHY
1.017 pu
P=2.0
Q=0.0
P=21.4
Q=0.7
28812 NEWBURG
0.989 pu
P=274.3
Q=153.6
2.5
4.4
21.4
20.3
4.7
2.7
177.0
1.6
28862 SUPERIOR
0.987 pu
29008 COLLINS
0.994 pu
P=23.0
Q=11.2
28703 SUPERIOR
1.025 pu
P=63.0
Q=0.0
P=297.4
Q=84.6
29043 WAYER
1.016 pu
P=9.0
Q=3.4
1.7
0.9
9 MW
7.5
5.2
28921 ARIZONA
0.995 pu
P=32.0
Q=8.0
0.4
0.8
201.4
13.5
100.6
18.6
28741 DAYTON
1.004 pu
28693 DAYTON
1.021 pu
P=86.6
Q=31.3
295.0
38.2
29016 JUDD
1.005 pu
JUDD1
JUDD2
JUDD3
JUDD4
28692 DIGIA
1.014 pu
P=7.8
Q=3.5
80.7
25.4
28980 SUMTR
1.011 pu
P=8.4
Q=4.0
89.3
29.5
29010 ALAMO
1.015 pu
P=5.0
Q=1.6
94.5
31.4
28726 BROWNSTOWN
1.026 pu
P=22.2
Q=12.6
28868 TC79
1.065 pu
28869 TC8
1.042 pu
29067 TC8
1.053 pu
P=115.0
Q=100.0
179.0
35.0
28896 VENDY
0.982 pu
P=33.7
Q=6.9
135.7
7.7
28910 A-B-VN
0.984 pu
81.5
10.5
28731 TOPAZ1
0.985 pu
54.6
4.4
28938 SPORT1
0.985 pu
54.6
4.6
54.6
4.6
28707 ALISON
0.987 pu
P=32.0
Q=19.0
86.7
23.7
28839 ROMULUS
0.996 pu
P=52.7
Q=34.1
29015 ELMTP
0.999 pu
372.4
5.8
28743 ELM
0.991 pu
P=25.5
Q=8.4
94.8
94.2
28694 ELM
1.034 pu
P=151.1
Q=68.0
28722 BROCK
0.984 pu
P=128.3
Q=74.4
28823 PERU
0.982 pu
P=32.1
Q=7.0

Contingency L3580-L4264



1. Trip Dayton Transformer
2-5. Drop Load at Romulus , Wayer, Digia & Dayton

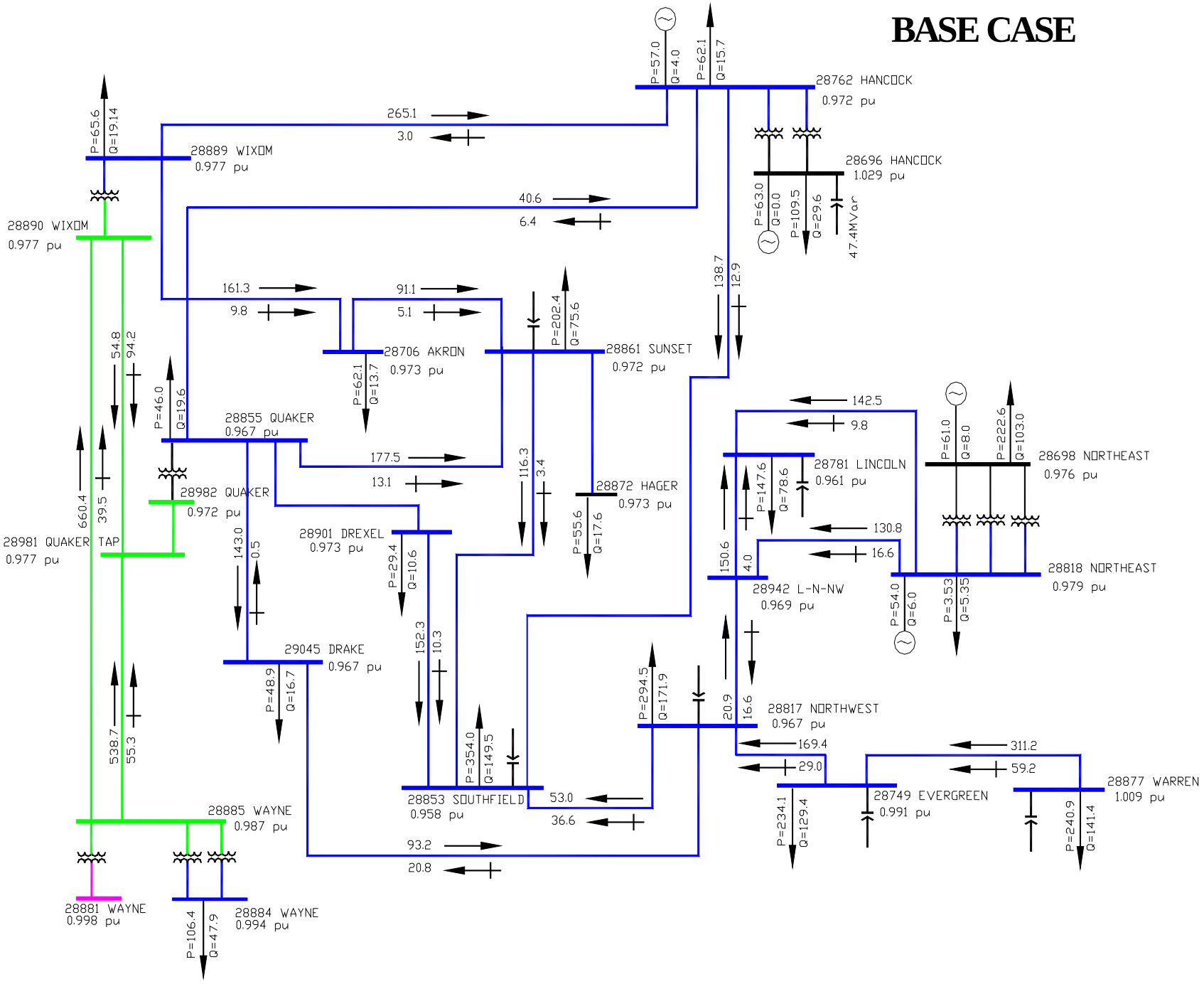


Category C Contingency that cannot be precluded as a cause for Widespread Outages

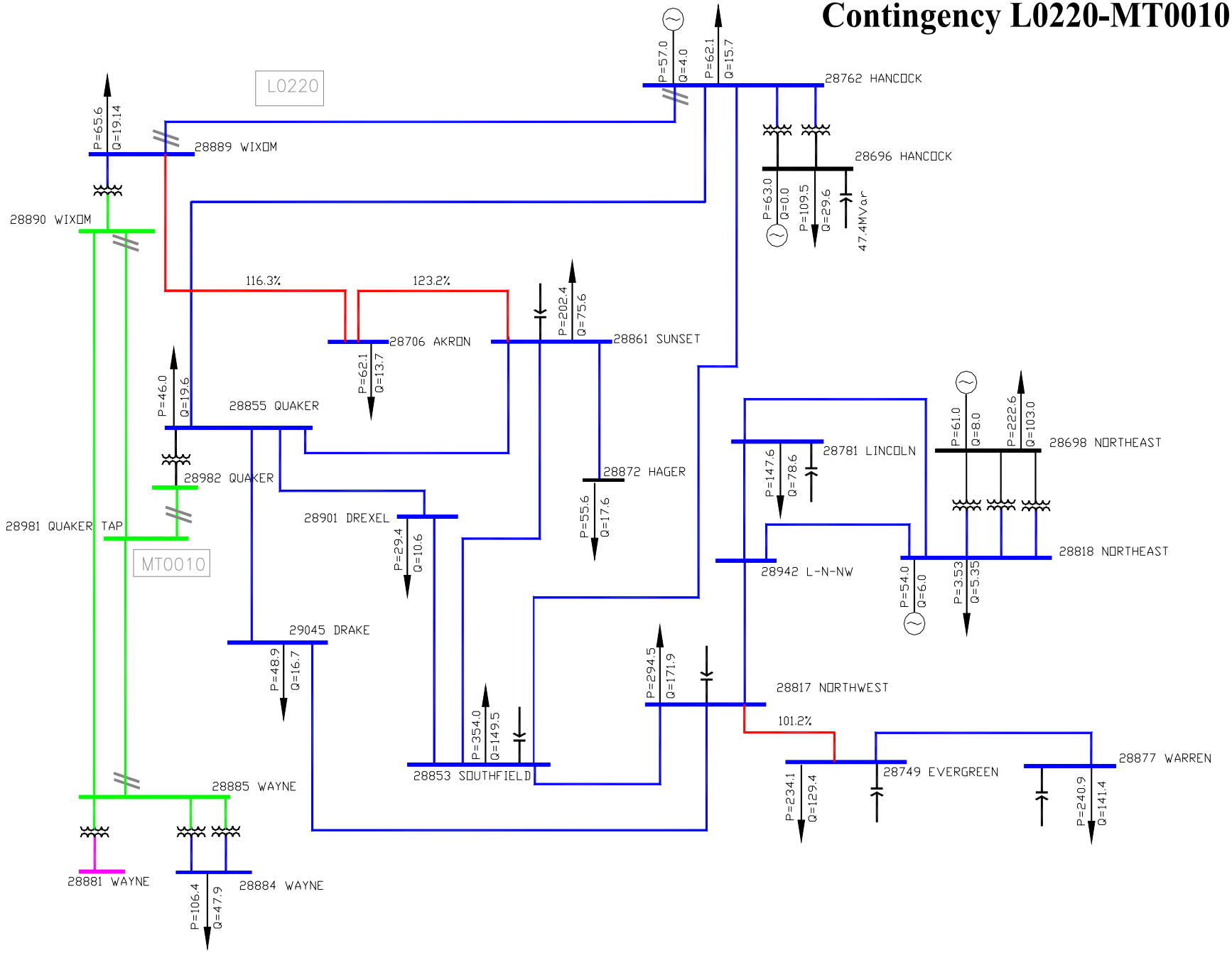
- Wayne-Wixom-Quaker 345 kV Multi-Terminal Line (MT010)
  Wixom to Hancock 120 kV Line (L0220)
- Loss of four lines:
  Akron to Sunset 120 kV (28706-28861-1)
  Evergreen to Northwest 120 kV (28749-28817-1)
  Northwest to L-N-NW 120 kV (28817-28942-1)
  Sunset to Haggerty Rd 120 kV (28861-28872-1)
- Load drop at five buses:
  Northwest (28817), Quaker (28855), Drexel (28901), Drake (29045), and Hancock (28782)
- Criteria: Loss of over 500 MW of Load

Commonwealth associates, inc.

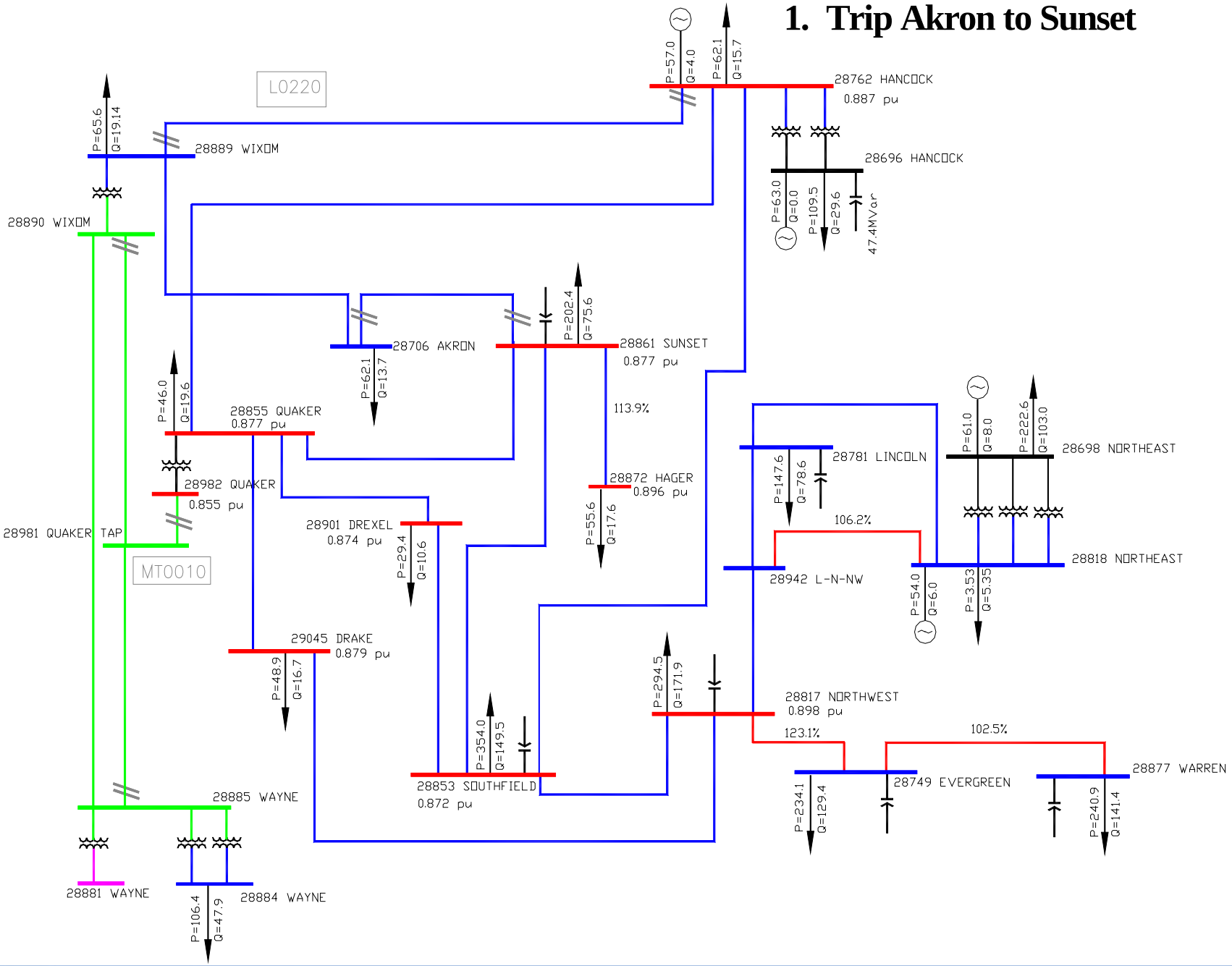
BASE CASE


28762 HANCOCK
0.972 pu
28696 HANCOCK
1.029 pu
28889 WIXOM
0.977 pu
28890 WIXOM
0.977 pu
28706 AKRON
0.973 pu
28861 SUNSET
0.972 pu
28855 QUAKER
0.967 pu
28982 QUAKER
0.972 pu
28981 QUAKER TAP
0.977 pu
28872 HAGER
0.973 pu
28901 DREXEL
0.973 pu
29045 DRAKE
0.967 pu
28781 LINCOLN
0.961 pu
28698 NORTHEAST
0.976 pu
28818 NORTHEAST
0.979 pu
28942 L-N-NW
0.969 pu
28817 NORTHWEST
0.967 pu
28853 SOUTHFIELD
0.958 pu
28749 EVERGREEN
0.991 pu
28877 WARREN
1.009 pu
28885 WAYNE
0.987 pu
28881 WAYNE
0.998 pu
28884 WAYNE
0.994 pu
47.4MVar

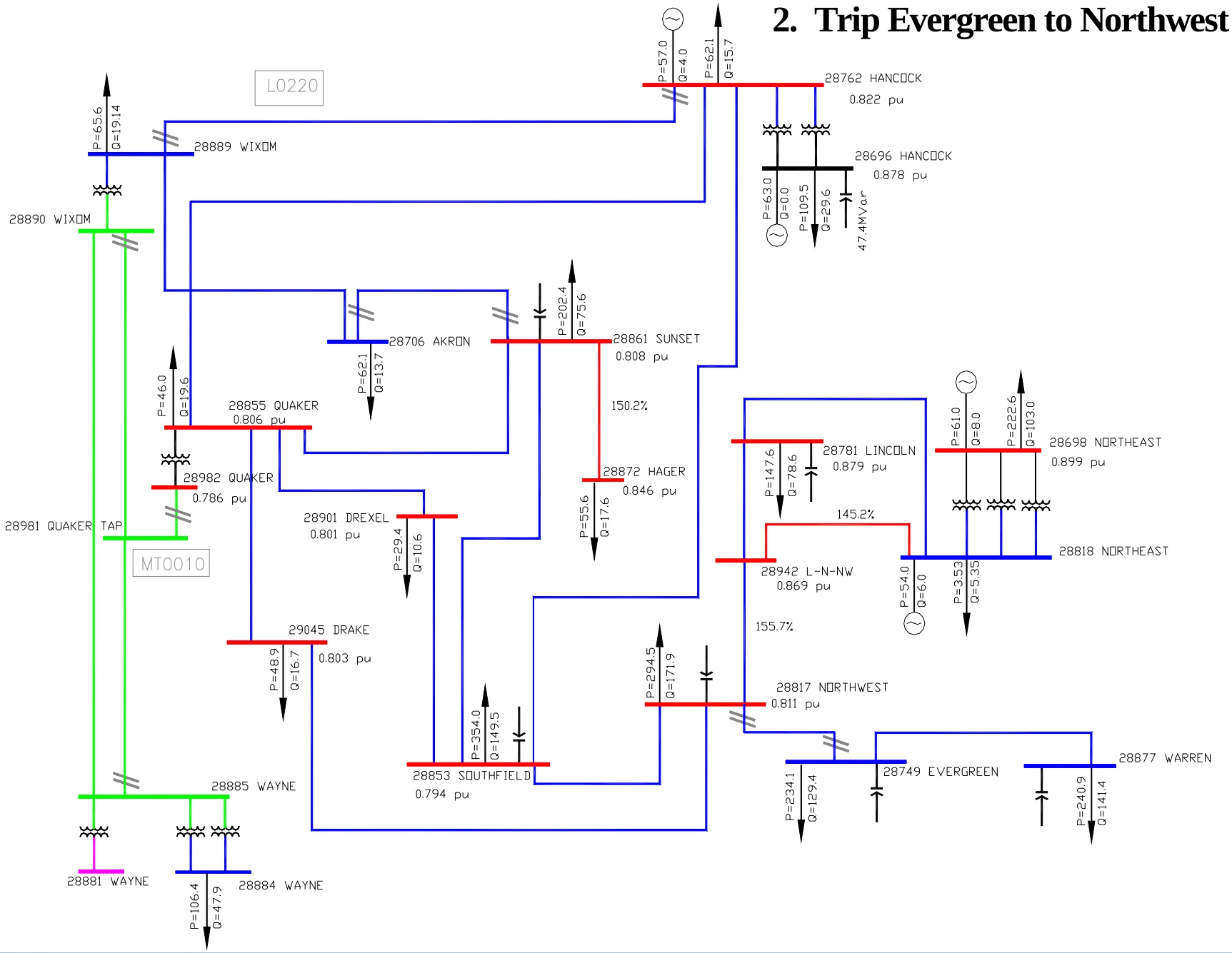
Contingency L0220-MT0010

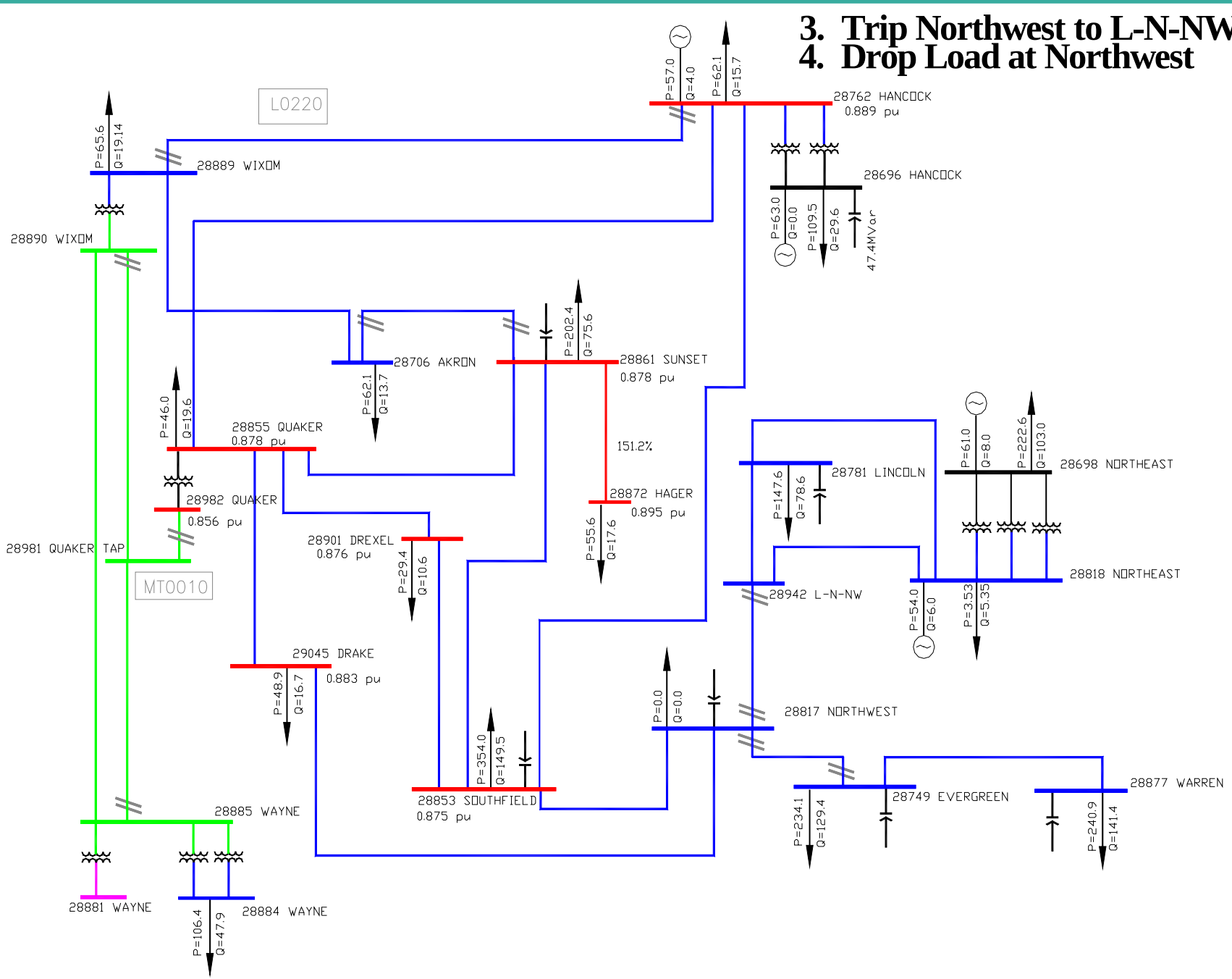


1. Trip Akron to Sunset

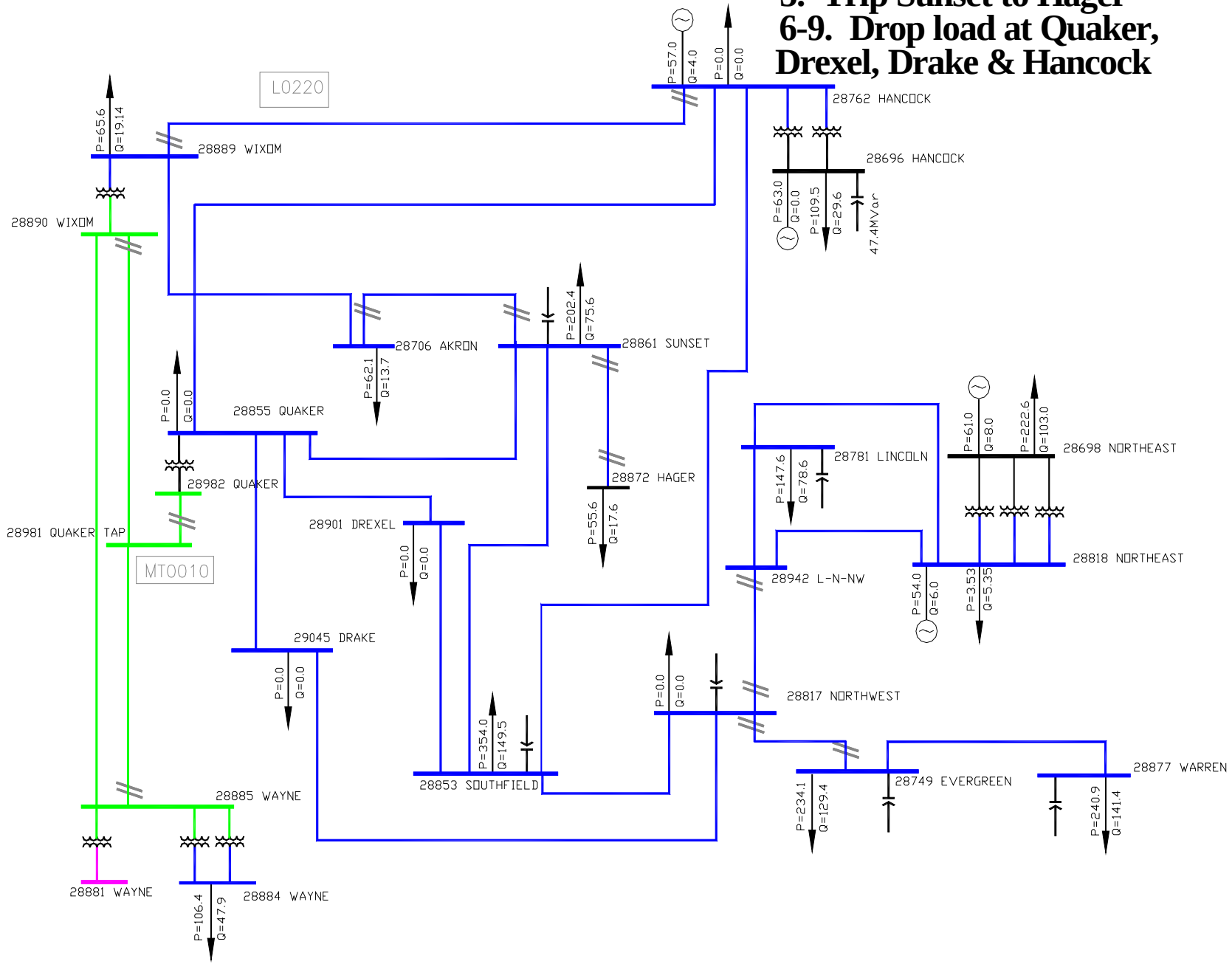


2. Trip Evergreen to Northwest




3. Trip Northwest to L-N-NW
4. Drop Load at Northwest
L0220
MT0010
28762 HANCOCK
0.889 pu
P=57.0
Q=4.0
P=62.1
Q=15.7
28696 HANCOCK
P=63.0
Q=0.0
P=109.5
Q=29.6
47.4MVar
28889 WIXOM
P=65.6
Q=19.14
28890 WIXOM
28706 AKRON
P=62.1
Q=13.7
28861 SUNSET
0.878 pu
P=202.4
Q=75.6
151.2%
28855 QUAKER
0.878 pu
P=46.0
Q=19.6
28982 QUAKER
0.856 pu
28981 QUAKER TAP
28872 HAGER
0.895 pu
P=55.6
Q=17.6
28901 DREXEL
0.876 pu
P=29.4
Q=10.6
28781 LINCOLN
P=147.6
Q=78.6
28698 NORTHEAST
P=61.0
Q=8.0
P=222.6
Q=103.0
28818 NORTHEAST
28942 L-N-NW
P=54.0
Q=6.0
P=3.53
Q=5.35
29045 DRAKE
0.883 pu
P=48.9
Q=16.7
28817 NORTHWEST
P=0.0
Q=0.0
28853 SOUTHFIELD
0.875 pu
P=354.0
Q=149.5
28749 EVERGREEN
P=234.1
Q=129.4
28877 WARREN
P=240.9
Q=141.4
28885 WAYNE
28881 WAYNE
28884 WAYNE
P=106.4
Q=47.9

5. Trip Sunset to Hager
6-9. Drop load at Quaker, Drexel, Drake & Hancock



An Abbreviated Study of a Real System

- Used NERC 2009 Summer Peak Case (2004 Series for 2005 Model Year)
- Contingencies only for the sub-system (390 buses, 550 branches)
- Monitored the sub-system and 2 buses away
- No verification of Category B operating procedures and liberal rating changes
- Liberal Category C criteria change (10% flow and voltage)
- Liberal cascade criteria (88% voltage and 110% overload

Commonwealth associates, inc.

Summary of Results for Category B

- Category B Contingency Standard Results
  - 2 contingencies diverged
  - 36 contingencies caused 41 overload violations (>100%)
  - 14 contingencies caused 56 low voltage violations (<0.90)

Commonwealth associates, inc.

Summary of Results for Category B

- Cascade Analysis for Category B Contingencies
  - 52 contingencies were run through the cascade tool
  - 1 aborted the cascade sequence because no further loads could be found to drop
  - 3 aborted because the 500 MW load drop limit had been reached
  - 19 resulted in some level of load drop
  - The four contingencies where the cascade sequence was aborted were NOT subsequently combined to create Category C contingencies

Commonwealth associates, inc.

Summary of Results for Category C

- Category C Contingency Generation
  - The 549 Category B contingencies have 150,426 possible unique combinations
  - Using sensitivity criteria of 10% flow change and voltage change to identify mutually-dependent combinations yielded 8,280 combinations. This is 5.5% of the total number of possible combinations.

Commonwealth associates, inc.

Summary of Results for Category C

- Category C Standard Results
  - 211 contingencies diverged
  - 1,893 contingencies caused 3,097 overload violations (>100%)
  - 454 contingencies caused 2,928 low voltage violations (<0.90)
  - The 2,354 (1.6% of the total possible combinations) contingencies causing these violations were subsequently run through the Cascade Analysis Tool

Commonwealth associates, inc.

Summary of Results for Category C

- Cascade Analysis for Category C Contingencies
  - 2 aborted the cascade sequence because no further loads could be found to drop
  - 3 aborted because the power flow solution interrupted in two consecutive attempts
  - 157 aborted because the 500 MW load drop limit had been reached

Commonwealth associates, inc.

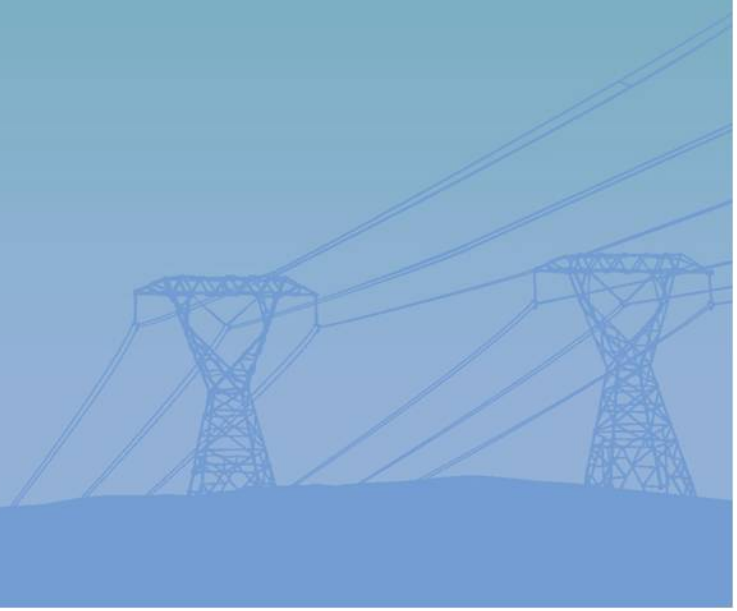
Priority List of Significant Contingencies

- 83 root cause contingencies have the potential for further cascade
- 80 root causes can be reasonably excluded as having the potential to lead to cascade

Commonwealth associates, inc.

Further Consideration

- Adding Probability Measures to the Assessment
- Geo-Referencing Substations
- Extending Screening to Transient Stability
- Periodic Usage
- Extend and Complete Automatic Contingency Generation



Commonwealth associates, inc.

Commonwealth Associates, Inc