Resilience in System Planning

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Existing PJM “planning criteria” conditions that result in a NERC Corrective Action Plan

Existing Planning Conditions Resulting in a Corrective Action Plan

- *Monitor for:*
  - *Voltage limits, voltage collapse, thermal limits, short circuit, stability*
- *Note:*
  - *Manual or automatic load shed is not permitted for any TPL-001-4 P0 - P7 condition.*

- **Single outage**
  - Generator, Transmission Circuit, Transformer, Shunt Device, Single Pole of a DC line, Opening of a line section without a fault

- **Bus section fault**

- **Stuck Breaker**
  - Loss of multiple elements caused by a stuck breaker attempting to clear a fault

- **Double circuit towerline**
  - The loss of any two adjacent (vertically or horizontally) circuits on a common structure.

- **N-1-1**
  - (single outage, followed by system adjustment, followed by another single outage)

PJM Planning M14B Attachment D-1 Load Loss Definitions

- Consequential vs. Non-consequential

- Consequential:
  - All Load that is no longer served by the Transmission system as a result of Transmission Facilities being removed from service by a Protection System operation designed to isolate the fault.

- Non-consequential:
  - Non-Interruptible Load loss that does not include: (1) Consequential Load Loss, (2) the response of voltage sensitive Load, or (3) Load that is disconnected from the System by end user equipment.

PJM Planning M14B Attachment D-1 Load Loss Definitions

- **Consequential Load Loss** – Consequential load loss occurs due to the design of the system but does not include automatic schemes designed to drop load under various conditions.
  - Examples:
    - A transformer serving radial load that taps a networked circuit.
    - Load that is served from a radial circuit.

- **Controlled Load Loss due to Automatic Schemes** – Controlled load loss occurs due to the operation of automatic schemes that are designed to drop load under specific maintenance conditions.

- **300 MW Planned Load Loss Limit** = Consequential load loss + Controlled load loss due to automatic schemes
  - The 300 MW total load loss limit is based, in part, on a Federal reporting requirement for major system incidents on electric power systems (refer to Electric Power System Emergency Report - Form EIA-417R).

- **Non-Consequential Load Loss** – If situations arise that are beyond the control of PJM that prevent the implementation of a Corrective Action Plan in the required timeframe, then Non Consequential Load Loss and curtailment of Firm Transmission Service are permitted to correct the situation that would normally not be permitted in Table 1, provided that PJM documents that they are taking actions to resolve the situation. PJM shall document the situation causing the problem, alternatives evaluated, and the use of Non-Consequential Load Loss or curtailment of Firm Transmission Service.

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NERC Extreme Events

- Ascending event severity:
- P0, P1, P2, P3, P4, P5, P6, P7 then Extreme

Table 1 – Steady State & Stability Performance Extreme Events

Steady State & Stability

For all extreme events evaluated:

a. Simulate the removal of all elements that Protection Systems and automatic controls are expected to disconnect for each Contingency.

b. Simulate Normal Clearing unless otherwise specified.

Steady State

1. Loss of a single generator, Transmission Circuit, single pole of a DC Line, shunt device, or transformer forced out of service followed by another single generator, Transmission Circuit, single pole of a different DC Line, shunt device, or transformer forced out of service prior to System adjustments.
2. Local area events affecting the Transmission System such as:
   a. Loss of a tower line with three or more circuits.[11]
   b. Loss of all Transmission lines on a common Right-of-Way[11].
   c. Loss of a switching station or substation (loss of one voltage level plus transformers).
   d. Loss of all generating units at a generating station.
   e. Loss of a large Load or major Load center.
3. Wide area events affecting the Transmission System based on System topology such as:
   a. Loss of two generating stations resulting from conditions such as:
      i. Loss of a large gas pipeline into a region or multiple regions that have significant gas-fired generation.
      ii. Loss of the use of a large body of water as the cooling source for generation.
      iii. Wildfires.
      iv. Severe weather, e.g., hurricanes, tornadoes, etc.
      v. A successful cyber attack.
      vi. Shutdown of a nuclear power plant(s) and related facilities for a day or more for common causes such as problems with similarly designed plants.
   b. Other events based upon operating experience that may result in wide area disturbances.

Stability

1. With an initial condition of a single generator, Transmission circuit, single pole of a DC line, shunt device, or transformer forced out of service, apply a 3Ø fault on another single generator, Transmission circuit, single pole of a different DC line, shunt device, or transformer prior to System adjustments.
2. Local or wide area events affecting the Transmission System such as:
   a. 3Ø fault on generator with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
   b. 3Ø fault on Transmission circuit with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
   c. 3Ø fault on transformer with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
   d. 3Ø fault on bus section with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
   e. 3Ø internal breaker fault.
   f. Other events based upon operating experience, such as consideration of initiating events that experience suggests may result in wide area disturbances

Resilience - Planning

- Resilience Criteria – Range of Possibilities
  - Do “no harm” (i.e. don’t make an existing problem worse)
  - Opportunistic – incorporate resilience as a factor in RTEP proposal selections
  - Standalone - address resilience as a stand-alone driver

- Resilience Criteria requires new analytical procedures and tools
  - Assess Vulnerabilities
  - Develop Resilience Indices

Resilience Next Steps