# Planning and Operating the Transmission System for Resiliency

**Center for Advanced Power Research**

**2018 IAB Spring Meeting**

**March 12-13, 2018**

# Planning and Operating the Transmission System for Resiliency

- The Definition(s) of Resilience
- The Duke Energy Transmission Grid(s)
- Grid vs. Component Resiliency
- The Basics of Planning the Transmission Grid
- Examples of System Design Changes that Enhance Resiliency
- The Challenges in Making a Business Case for Grid Resiliency

# Planning and Operating the Transmission System for Resiliency

## The Definition(s) of Resilience

### The Duke Energy definition:

*Resilience* - the ability of the system and/or its components to prepare for and adapt to changing conditions, withstand and rapidly recover from all types of disruptions, whether deliberate, accidental or naturally occurring.

While resilience is related to aspects of both reliability and security, it incorporates advanced preparation and a dynamic response capability to reduce the magnitude and duration of energy service disruptions under a range of stressful conditions, from every day occurrences to high impact low frequency events. Associated infrastructure planning and investment strategies broaden the range of risk-reduction options and improve flexibility through activities both pre- and post-disruption.

# Planning and Operating the Transmission System for Resiliency

## The Definition(s) of Resilience

From NATF – resiliency relates to preparing for, operating through, and recovering from a high impact, low frequency (HILF) event, such as a hurricane, geomagnetic disturbance (GMD) event, or high altitude electromagnetic pulse (HEMP) attack.

From the National Infrastructure Advisory Council - *“…the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.”*

## The Definition(s) of Resilience

What is the difference between reliability and resilience?

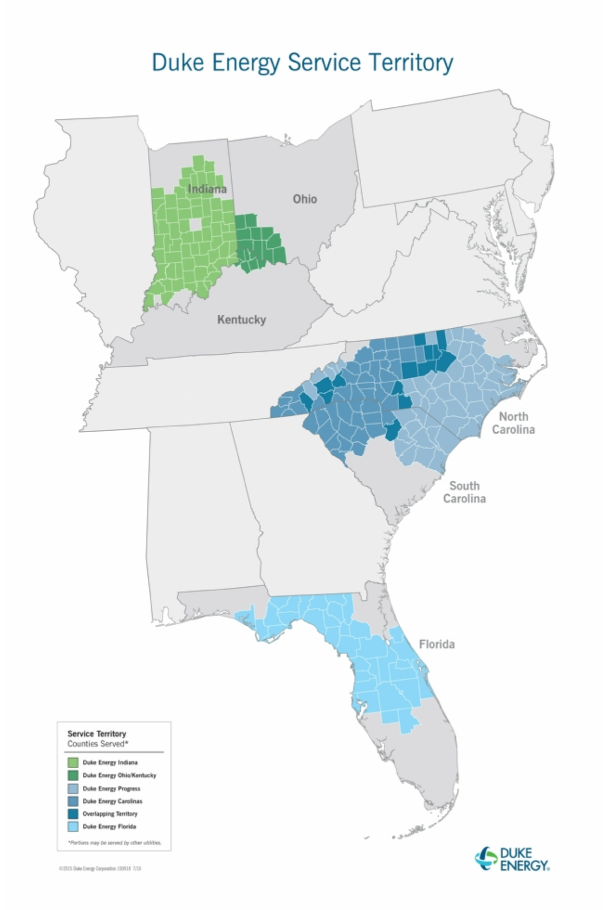
Reliability means that lights are always on in a consistent manner. This is a binary view of system performance where systems are either functional or failed.  (Keeping the lights on)

Resilience approaches emphasize the idea that disruptive events occur regularly and that systems should be designed to bounce back quicker and stronger because the impact was less. (Get the lights back on more quickly, with fewer impacted.)

A system can be reliable but not resilient, meaning that under normal range of circumstances, the performance of a grid can be well within the extent of expectation

# Planning and Operating the Transmission System for Resiliency

## The Duke Energy Transmission Grid(s)



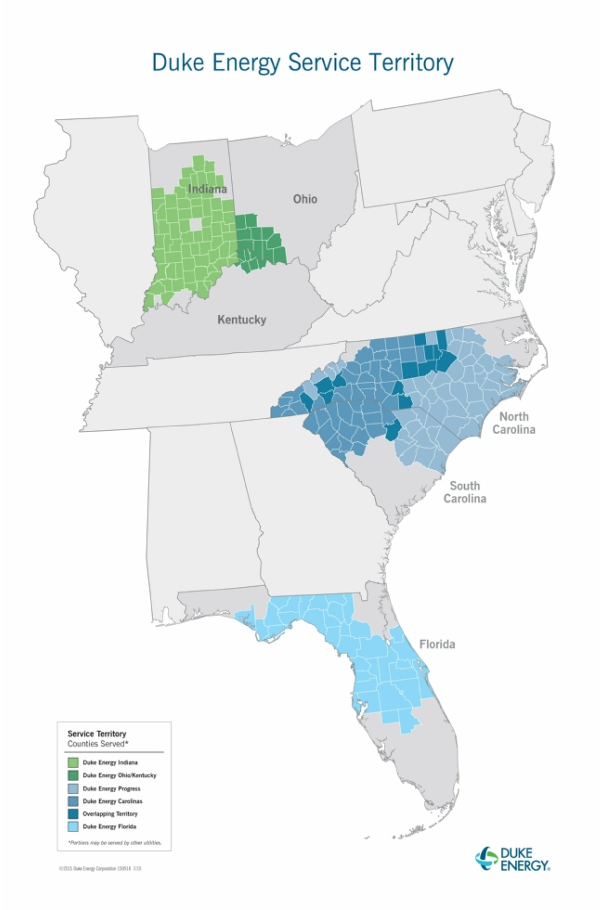

Duke Energy Operates in 5 different Planning Authorities

- Duke Energy Indiana – MISO
- Duke Energy Ohio/Kentucky – PJM
- Duke Energy Carolinas (Western NC/SC)
- Duke Energy Progress (Eastern NC/SC)
- Duke Energy Florida

The systems have evolved differently and therefore have different planning & resiliency issues

# Planning and Operating the Transmission System for Resiliency

## The Duke Energy Transmission Grid(s)




Highlights of system differences

- Duke Energy Indiana – Jointly owned transmission system
- Duke Energy Ohio/Kentucky – Concentrated load area
- Duke Energy Carolinas – Double circuit lines
- Duke Energy Progress – No transmission < 100 kV
- Duke Energy Florida - Heavy use of 69 kV “grid”

# Planning and Operating the Transmission System for Resiliency

## Grid vs. Component Resiliency

Much of the discussion of resilience has focused on improving the ability of grid components to withstand **extreme** events:

- Concrete vs. wood poles
- Elevated substations above 100 year flood plain
- Undergrounding transmission lines
- Increasing transformer spare availability
- Redundancy of devices, e.g., relays, CTs/PTs, power supplies

# Planning and Operating the Transmission System for Resiliency

## Grid vs. Component Resiliency

There has been less discussion of designing the overall system to prepare for, adapt to and recover from events:

- Increasing remote switching capability (automated switching?)
- Providing multiple supply paths to load centers
- Increasing situational awareness
- Planning for more extreme events

One reason for this difference in focus is that the Transmission planning process already provides some level of resilience, and adding more may be challenging to justify. (And, there has been a focus on major events more recently.)

# Planning and Operating the Transmission System for Resiliency

## The Basics of Planning the Transmission Grid

For voltages >/= 100 kV, planning of the transmission system is governed by standards set by the North American Electric Reliability Corporation (NERC). The standards are enforced through regular review and audits by the regional reliability organizations (SERC, FRCC, Reliability First, etc.), and compliance violations are subject to fines.

For voltages < 69 kV, planning is governed by standards set by the individual Planning Authority or regional agreements. Generally, they are similar to the NERC standards.

The planning standards are prescriptive in the conditions that must be evaluated, and broadly direct the solutions that must be implemented when problems are found. In a sense, planning to the standards could be considered an exercise is adding system resiliency, to prepare for and withstand a prescribed level of events.

# Planning and Operating the Transmission System for Resiliency

## The Basics of Planning the Transmission Grid

Standard TPL-001-4 — Transmission System Planning Performance Requirements

**Table 1 – Steady State & Stability Performance Planning Events**

**Steady State & Stability:**

a. The System shall remain stable. Cascading and uncontrolled islanding shall not occur.
b. Consequential Load Loss as well as generation loss is acceptable as a consequence of any event excluding P0.
c. Simulate the removal of all elements that Protection Systems and other controls are expected to automatically disconnect for each event.
d. Simulate Normal Clearing unless otherwise specified.
e. Planned System adjustments such as Transmission configuration changes and re-dispatch of generation are allowed if such adjustments are executable within the time duration applicable to the Facility Ratings.

**Steady State Only:**

f. Applicable Facility Ratings shall not be exceeded.
g. System steady state voltages and post-Contingency voltage deviations shall be within acceptable limits as established by the Planning Coordinator and the Transmission Planner.
h. Planning event P0 is applicable to steady state only.
i. The response of voltage sensitive Load that is disconnected from the System by end-user equipment associated with an event shall not be used to meet steady state performance requirements.

**Stability Only:**

j. Transient voltage response shall be within acceptable limits established by the Planning Coordinator and the Transmission Planner.

| Category | Initial Condition | Event [1] | Fault Type [2] | BES Level [3] | Interruption of Firm Transmission Service Allowed [4] | Non-Consequential Load Loss Allowed |
|---|---|---|---|---|---|---|
| **P0** No Contingency | Normal System | None | N/A | EHV, HV | No | No |
| **P1** Single Contingency | Normal System | Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer [5] 4. Shunt Device [6] | 3Ø | EHV, HV | No[9] | No[12] |
| | | 5. Single Pole of a DC line | SLG | | | |
| **P2** Single Contingency | Normal System | 1. Opening of a line section w/o a fault [7] | N/A | EHV, HV | No[9] | No[12] |
| | | 2. Bus Section Fault | SLG | EHV | No[9] | No |
| | | | | HV | Yes | Yes |
| | | 3. Internal Breaker Fault [8] (non-Bus-tie Breaker) | SLG | EHV | No[9] | No |
| | | | | HV | Yes | Yes |
| | | 4. Internal Breaker Fault (Bus-tie Breaker) [8] | SLG | EHV, HV | Yes | Yes |

8

From the NERC Planning Standard TPL-001-4 – Table 1 describes the system performance standards that must be met, and the conditions that need to be evaluated.

# Planning and Operating the Transmission System for Resiliency

## The Basics of Planning the Transmission Grid

**Standard TPL-001-4 — Transmission System Planning Performance Requirements**

| Category | Initial Condition | Event [1] | Fault Type [2] | BES Level [3] | Interruption of Firm Transmission Service Allowed [4] | Non-Consequential Load Loss Allowed |
|---|---|---|---|---|---|---|
| **P3** Multiple Contingency | Loss of generator unit followed by System adjustments[9] | Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer [5] 4. Shunt Device [6] | 3Ø | EHV, HV | No[9] | No[12] |
| | | 5. Single pole of a DC line | SLG | | | |
| **P4** Multiple Contingency *(Fault plus stuck breaker[10])* | Normal System | Loss of multiple elements caused by a stuck breaker [10](non-Bus-tie Breaker) attempting to clear a Fault on one of the following: 1. Generator 2. Transmission Circuit 3. Transformer [5] 4. Shunt Device [6] 5. Bus Section | SLG | EHV | No[9] | No |
| | | | | HV | Yes | Yes |
| | | 6. Loss of multiple elements caused by a stuck breaker[10] (Bus-tie Breaker) attempting to clear a Fault on the associated bus | SLG | EHV, HV | Yes | Yes |
| **P5** Multiple Contingency *(Fault plus relay failure to operate)* | Normal System | Delayed Fault Clearing due to the failure of a non-redundant relay[13] protecting the Faulted element to operate as designed, for one of the following: 1. Generator 2. Transmission Circuit 3. Transformer [5] 4. Shunt Device [6] 5. Bus Section | SLG | EHV | No[9] | No |
| | | | | HV | Yes | Yes |
| **P6** Multiple Contingency *(Two overlapping singles)* | Loss of one of the following followed by System adjustments.[9] 1. Transmission Circuit 2. Transformer [5] 3. Shunt Device[6] 4. Single pole of a DC line | Loss of one of the following: 1. Transmission Circuit 2. Transformer [5] 3. Shunt Device [6] | 3Ø | EHV, HV | Yes | Yes |
| | | 4. Single pole of a DC line | SLG | EHV, HV | Yes | Yes |
| **P7** Multiple Contingency *(Common Structure)* | Normal System | The loss of: 1. Any two adjacent (vertically or horizontally) circuits on common structure [11] 2. Loss of a bipolar DC line | SLG | EHV, HV | Yes | Yes |



### And, per the standard:

**2.7.** For planning events shown in Table 1, **when the analysis indicates an inability of the System to meet the performance requirements in Table 1, the Planning Assessment shall include Corrective Action Plan(s) addressing how the performance requirements will be met.** Revisions to the Corrective Action Plan(s) are allowed in subsequent Planning Assessments but the planned System shall continue to meet the performance requirements in Table 1. Corrective Action Plan(s) do not need to be developed solely to meet the performance requirements for a single sensitivity case analyzed in accordance with Requirements R2, Parts 2.1.4 and 2.4.3. The Corrective Action Plan(s) shall:

**2.7.1.** List System deficiencies and the associated actions needed to achieve required System performance. Examples of such actions include:

- **Installation, modification, retirement, or removal of Transmission and generation Facilities and any associated equipment.**
- Installation, modification, or removal of Protection Systems or Special Protection Systems
- Installation or modification of automatic generation tripping as a response to a single or multiple Contingency to mitigate Stability performance violations.
- Installation or modification of manual and automatic generation runback/tripping as a response to a single or multiple Contingency to mitigate steady state performance violations.
- **Use of Operating Procedures specifying how long they will be needed as part of the Corrective Action Plan.**
- Use of rate applications, DSM, new technologies, or other initiatives.

# Planning and Operating the Transmission System for Resiliency

## The Basics of Planning the Transmission Grid

The Table 1 contingencies that must be evaluated include a number of multiple contingency combinations, for example:

- Loss of a generator followed by loss of another element (P3 event, in the vernacular)
- Loss of multiple elements following a stuck breaker (P4)
- Loss of multiple elements following failure of a non-redundant relay (P5)
- Loss of a line followed by system adjustments and loss of a second line (P6), also known as N-1-1
- Etc.

As the contingencies become more severe, the standards allow loss of customer load, rather than require a Corrective Action Plan.  Resiliency has been designed into the system through application of these standards.

# Planning and Operating the Transmission System for Resiliency

## The Basics of Planning the Transmission Grid

Transmission Planning is also now becoming more prescriptive for **extreme** events. For example:

- NERC Standard TPL-007 requires planning for geomagnetic disturbances.
- NERC Standard CIP-014 requires planning for physical security events, such as loss of entire substations due to a physical attack.

There are also concerns over electromagnetic pulse (EMP) attacks and cyber attacks. More and more, resiliency is being "planned" into the system, at least for the extreme events.

# Planning and Operating the Transmission System for Resiliency

## Examples of System Design Changes that Enhance Resiliency

However, additional resiliency can be planned into the system by going above and beyond the standard requirements to withstand these events. For example:

- For N-1-1 contingencies (P6), projects could be implemented (new lines, substations, etc.) that would reduce or eliminate the allowed load loss when the contingency occurs.
- The system can be reconfigured to reduce the amount of load exposed to outages.
- Additional redundancy can be added to protection systems, line configurations (e.g., parallel circuits)

Measures to prepare for events:

- Identification of critical facilities where physical security measures should be enhanced (Actually a planning-related critical infrastructure NERC standard).

# Planning and Operating the Transmission System for Resiliency

## Examples of System Design Changes that Enhance Resiliency

Measures to <u>recover</u> from events:

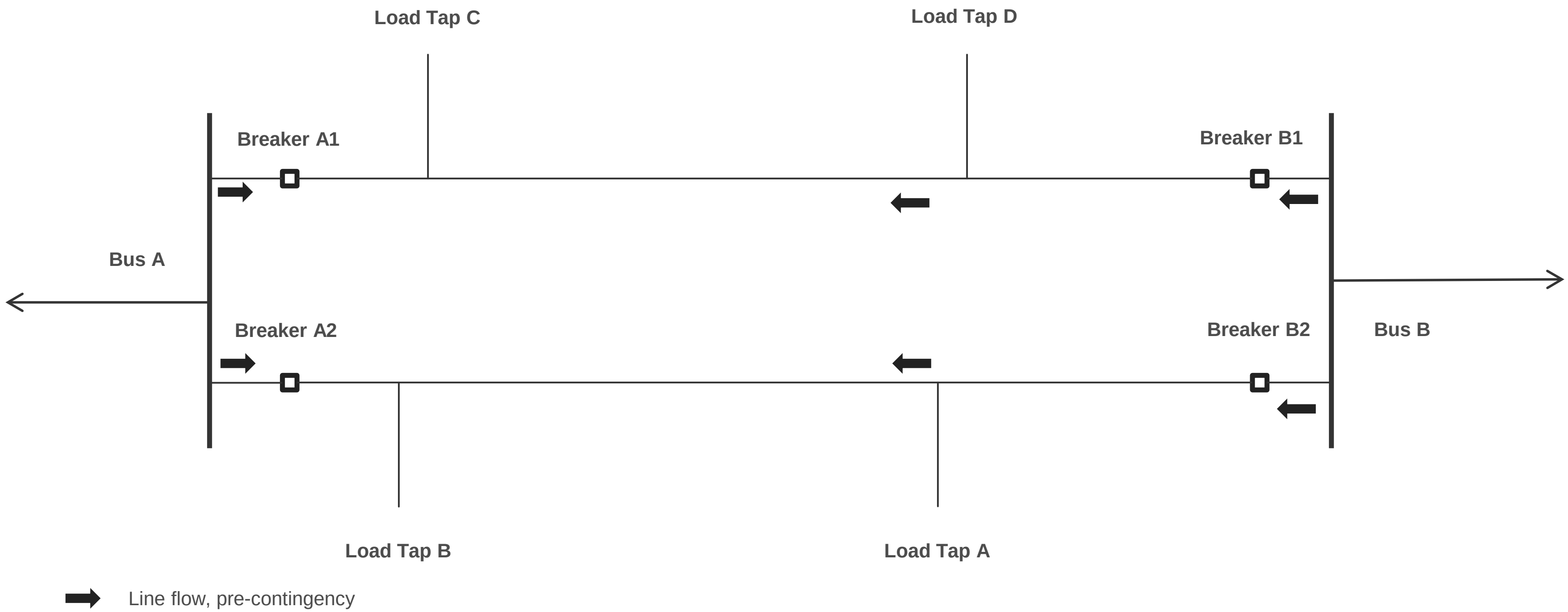
- Looping in customer load delivery points versus radial feeds to allow multiple feed capability
- Segmenting transmission lines with remote switching capability to isolate outages.
- Load swapover capability on parallel circuits

Measures to <u>adapt</u> to changing conditions:

- Identification of pre-contingency operating procedures that can be implemented to minimize outages

All of these are part of the transmission planning process when resiliency is an objective.

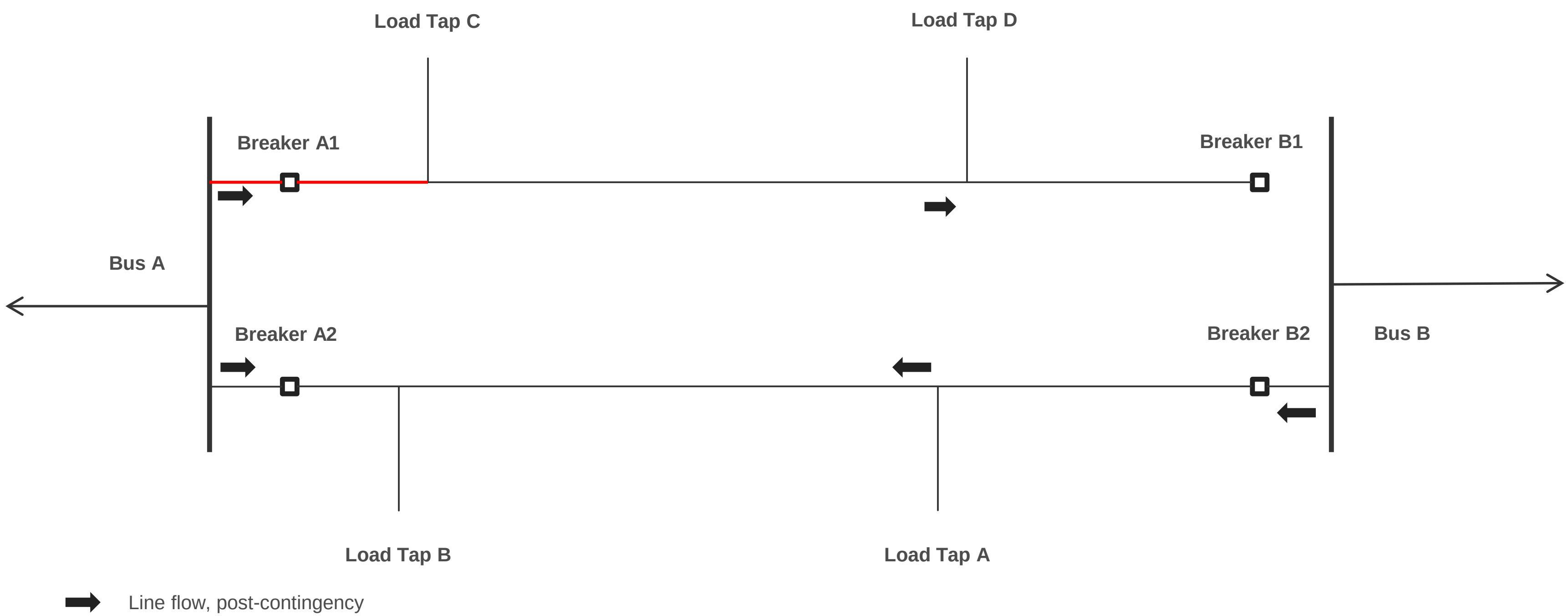
## Examples of System Design Changes that Enhance Resiliency




Consider the example of a double circuit line with loads tapped from both circuits. A breaker (B1) opens on one line (no line fault).

# Planning and Operating the Transmission System for Resiliency

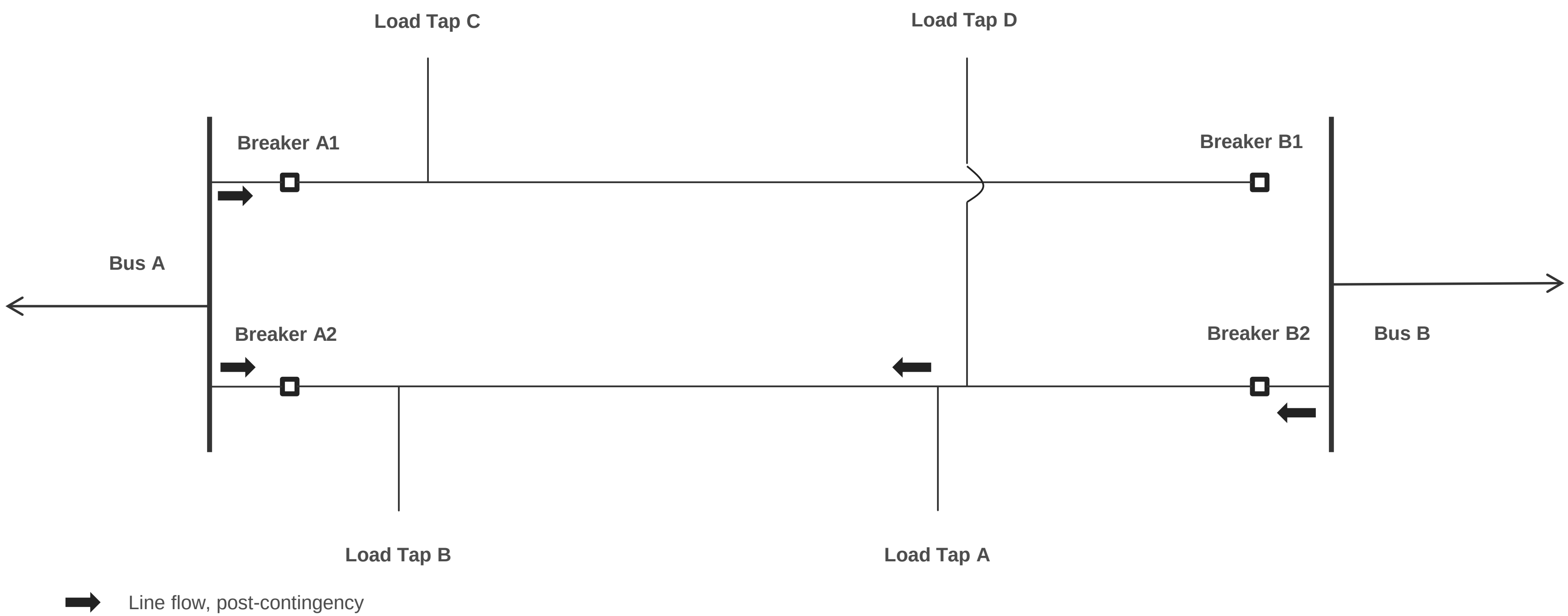
## Examples of System Design Changes that Enhance Resiliency




With breaker B1 open, the first circuit(A1-B1) must now carry the total of loads C and D across the first and second line segments, and the segment from Bus A to Load Tap C is now overloaded. Load at Tap D would have to be shed to alleviate the overload until Breaker B1 can be addressed.

# Planning and Operating the Transmission System for Resiliency

## Examples of System Design Changes that Enhance Resiliency




If Load D could be swapped over to the second circuit, the overload could be alleviated, or the segment from Bus A to Load Tap C could be rebuilt.

# Planning and Operating the Transmission System for Resiliency

## The Challenges in Making a Business Case for Grid Resiliency

How can benefits be quantified?

- Risks of contingencies beyond those addressed by the TPL standards are considered low
- Planning standards are deterministic. No recognition of customer impacts (SAIDI, SAIFI, etc.)
- A basis for determining which projects should be done must be developed. Load based? Distance based? Identification of “critical” loads?
- Cost/benefit calculation is difficult to quantify

# Questions?