Reliability Metrics

SAIDI - system annual interruption duration index
SAIFI - system annual interruption frequency index
CAIDI - customer annual interruption duration index
CAIFI - customer annual interruption frequency index

3 customers instead of system
Resilient Systems

Fig. 3. Observed Outages to the Bulk Electric System
Source: U.S. Energy Information Administration

Reliability

• NERC Definition
  » Reliability. The ability of the bulk power system to withstand sudden disturbances, such as electric short circuits or the unanticipated loss of system elements from credible contingencies, while avoiding uncontrolled cascading blackouts or damage to equipment
**Adequacy**

- **NERC Definition**
  
  » *Adequacy.* "The ability of the electricity system to supply the aggregate electrical demand and energy requirements of the end-use customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements."

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**Critical Infrastructure Resilience**

- **National Infrastructure Advisory Council definition:**
  
  » critical infrastructure resilience is 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."
Components degrade or fail
- People make mistakes
- Nature will intervene
- Weather, earthquakes, geomagnetic storms

People will...
- mischief
A resilient control system is one that maintains state awareness and an accepted level of operational normalcy in response to disturbances, including threats of an unexpected and malicious nature.

https://en.wikipedia.org/wiki/Resilient_control_systems
### DIRE Curve Definitions

**Adaptability**: The derivative of the disturbance curve. This average defines the ability of the system to resist degradation on the downward slope, but also to recover on the upward. Primarily considered a time based term that indicates impact to mission. Considers both short term system and longer term human responder actions.

**Adaptive Capacity**: The ability of the system to adapt or transform from impact and maintain minimum normalcy. Considered a value between 0 and 1, where 1 is fully operational and 0 is the resilience threshold.

**Adaptive Insufficiency**: The inability of the system to adapt or transform from impact, indicating an unacceptable performance loss due to the disturbance. Considered a value between 0 and -1, where 0 is the resilience threshold and -1 is total loss of operation.

**Brittleness**: The area under the disturbance curve as intersected by the resilience threshold. This indicates the impact from the loss of operational normalcy.

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### Phases of Resilient Control System Preparation and Disturbance Response:

- **Prepare**: Maintaining proactive state awareness of system conditions and degradation
- **Resist**: System response to recognized conditions, both to mitigate and counter
- **Respond**: System degradation has been stopped and returning system performance
- **Restore**: Longer term performance restoration, which includes equipment replacement

**Resiliency**: The converse of brittleness, which for a resilience system is "zero" loss of minimum normalcy.

**Robustness**: A positive or negative number associated with the area between the disturbance curve and the resilience threshold, indicating either the capacity or insufficiency, respectively.
Disturbance and Impact Resilience Evaluation Curve

DIRE

- Disturbances affect performance in cognitive, cyber and physical ways
  - Physical networks slow down and sensors fail
  - Hackers impact data and network throughput
  - Humans react differently, sometimes incorrectly and slow
- Automation
  - Control
  - Communication

- Human Interface

- Cybersecurity/Physical Security

2. How do communicate to operators about a possible cyberattack or an actual one