Dynamic Line Rating as a Means to Enhance Transmission Grid Resilience

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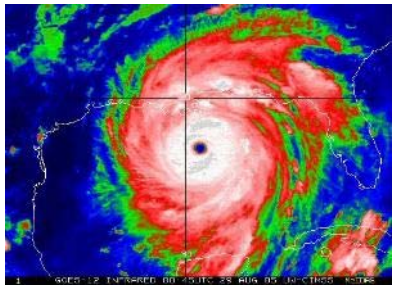
CIGRE US National Committee
2015 Grid of the Future Symposium

GRID RESILIENCY:
Failure Resistance with Rapid Recovery

- Many causes to power system events that prevent serving load
- Short Term OR Long Term Effects
- Weather
- Willful Attack
- Cascade Trips



Dynamic Line Rating and Forecasting

SIMPLY PUT:

Compared to transmission line static ratings, **DLR provides**:

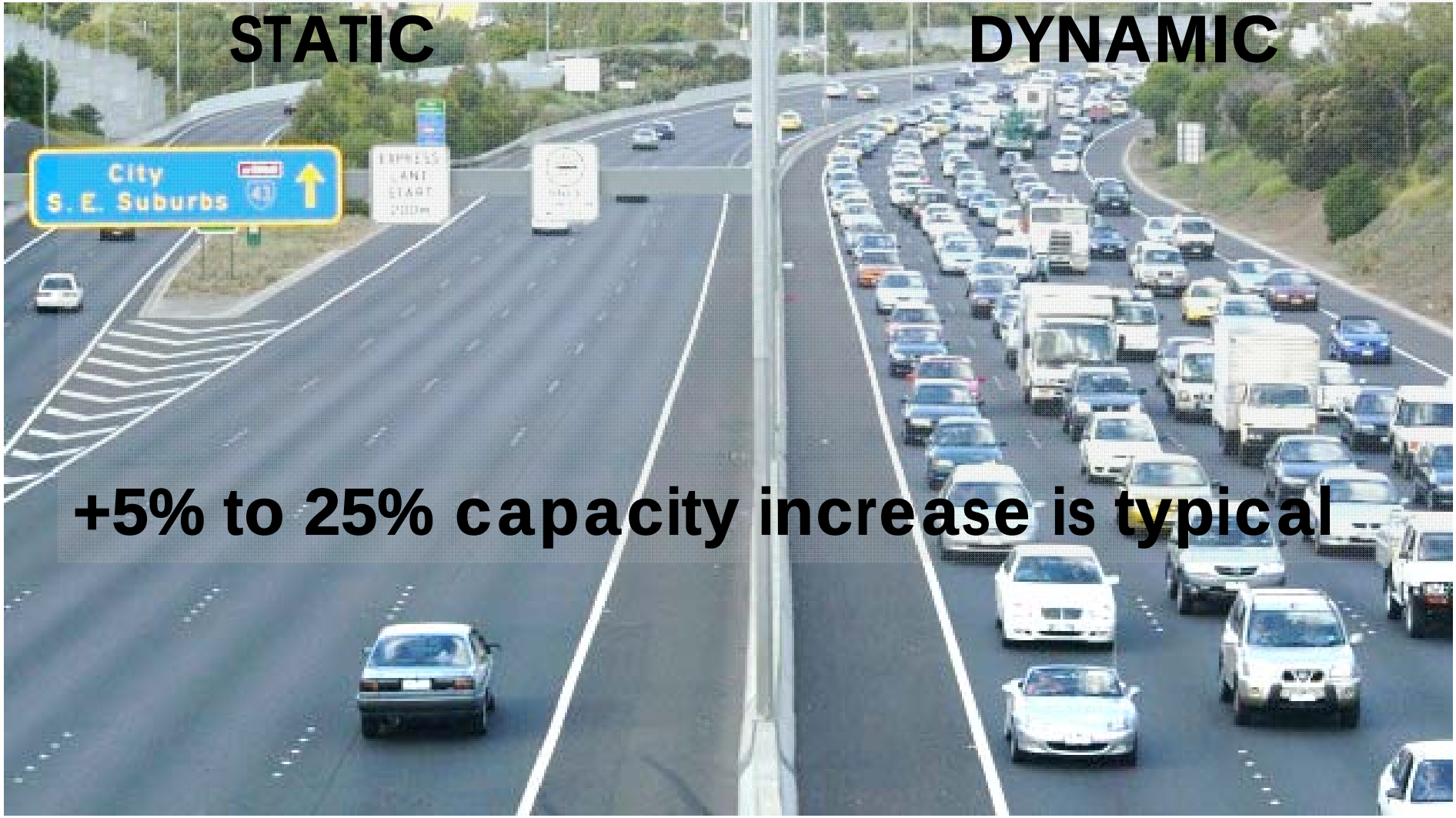
- **Real-time, or**
- **Forecasted**

Transmission line capacity taking into account:

- Line clearance
- Conductor temp
- Weather and current

Dynamic Line Rating and Forecasting

That is, how much a line can <u>really</u> handle



+5% to 25% capacity increase is typical

Major Asset Losses May Require Long Term Rating Increases

- **Major losses take time to restore**
  - Multiple downed towers
  - Destroyed substations
- **Rapid Recovery Requires:**
  - Access to spares
  - Time to install
- **The Grid must to adapt to the change in power flows around the damage**
  - Normal economic dispatch patterns may impossible
  - Remaining paths may become constrained
  - Lower voltage lines may need to absorb more power flow
    - **These lines are often more difficult to justify for contingency upgrades**

DLR with Long Term Recovery Events

When preemptively installed DLR:

- **Can provide "emergency equivalent" ratings of remaining lines in both real-time and forecast modes to address both the short- and medium-term**
- **Addresses various challenges during recovery:**
  - **Varying amounts and types of generation**
  - **Economic dispatch issues**
  - **Varying grid topology**
    - ➢ **DLR provides an equally dynamic and flexible network where constraints may be more easily mitigated**
- **Economically and Quickly provides the strong 138kV and 230kV networks needed during loss of major lines**
  - **Upgrades are often difficult to justify economically**
  - **DLR is a cost effective, fast alternative to reconductoring, etc**
  - **Frees up capital for more attractive investments**

Cascading Outages

- Cascading loss of transmission paths is a common cause of blackouts
- Cascading outages are where one event leads to another until a collapse occurs
- The August 2003 blackout is a recent example

Cascading Outage Research

- Ironically, the more complex and tightly integrated a network is, the more fragile it becomes

- X-axis is load fluctuation from any cause. Assume from a cascading event
- Y-axis is fraction of lines that trip
- Note as complexity increase, so does the propensity to collapse

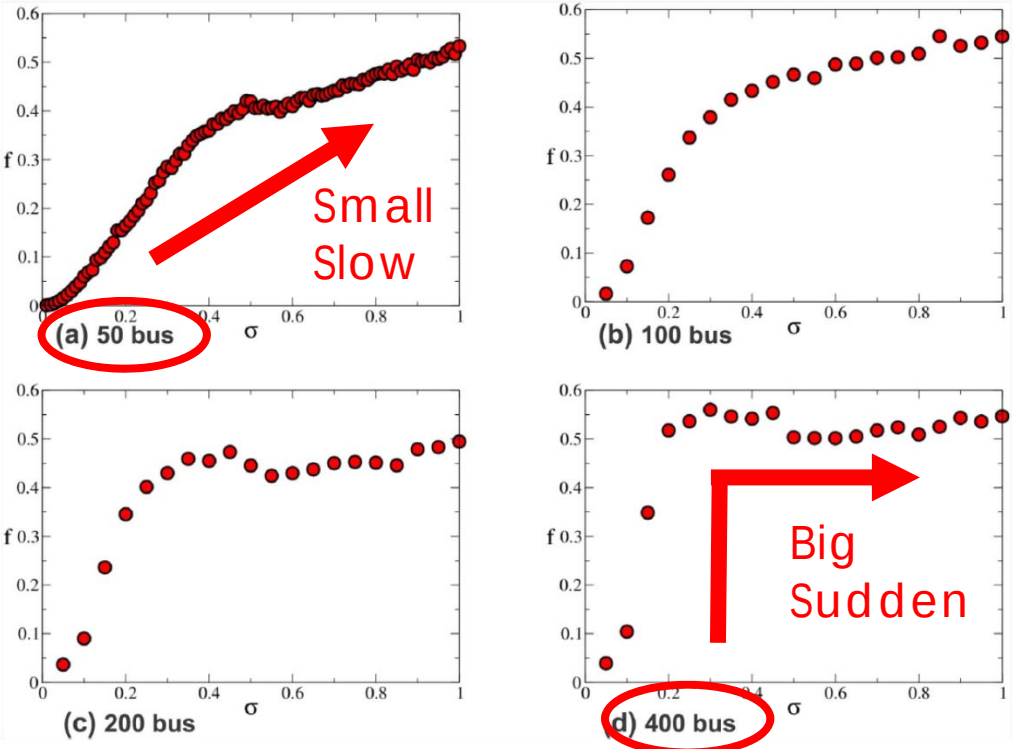


Figure 5 from "Abruptness of Cascade Failures in Power Grids," Nature.com, Pahwa, Scoglio & Scala, 2014

DLR as Possible Means to Ameliorate Cascading Outages

- **Line related cascade failures occur when line capacity is exceeded**
  - All buses/lines (or nodes/links) are treated as having fixed capacities

- **DLR may provide a new option by replacing fixed limits with dynamic real-time limits during events**
- **Example: August 2003 blackout contributing cause:**
  - Zone-3 distance relays tripped to prohibit lines from exceeding fixed static emergency overload ratings
    - ➢ **DLR could allow for dynamic Zone-3 relay settings by adapting for actual overload capacity**

DLR as an Economically Positive Resilience Solution

- **Typical Grid Resilience Expenditures are Expenses**
  - Spares
  - Redundant systems
  - Walls
  - Video Cameras
- **In contrast, DLR Provides Positive Economic Benefits when NOT being used for Resilience**
  - Reductions in congestion expense
  - Provides additional capacity for energy trading
  - Least cost solution for moderate capacity upgrades
  - Cost effective line clearance compliance tool
  - And more

Rapid Payback from Ongoing Economic Benefits of DLR

Summary

DLR should be considered as a Grid Resilience tool

- Provides “emergency equivalent” ratings during longer term recovery events
- Replaces fixed networks with dynamic and flexible networks where constraints during recovery may be more easily mitigated
- Provides an economical and time-efficient alternative to upgrading “on the cusp” sub-transmission lines for N-1 scenarios
- Provides possible new tool for use in avoiding cascading events
- Provides daily operational benefits resulting in rapid payback