Transmission Planning in the Face of Natural Disasters

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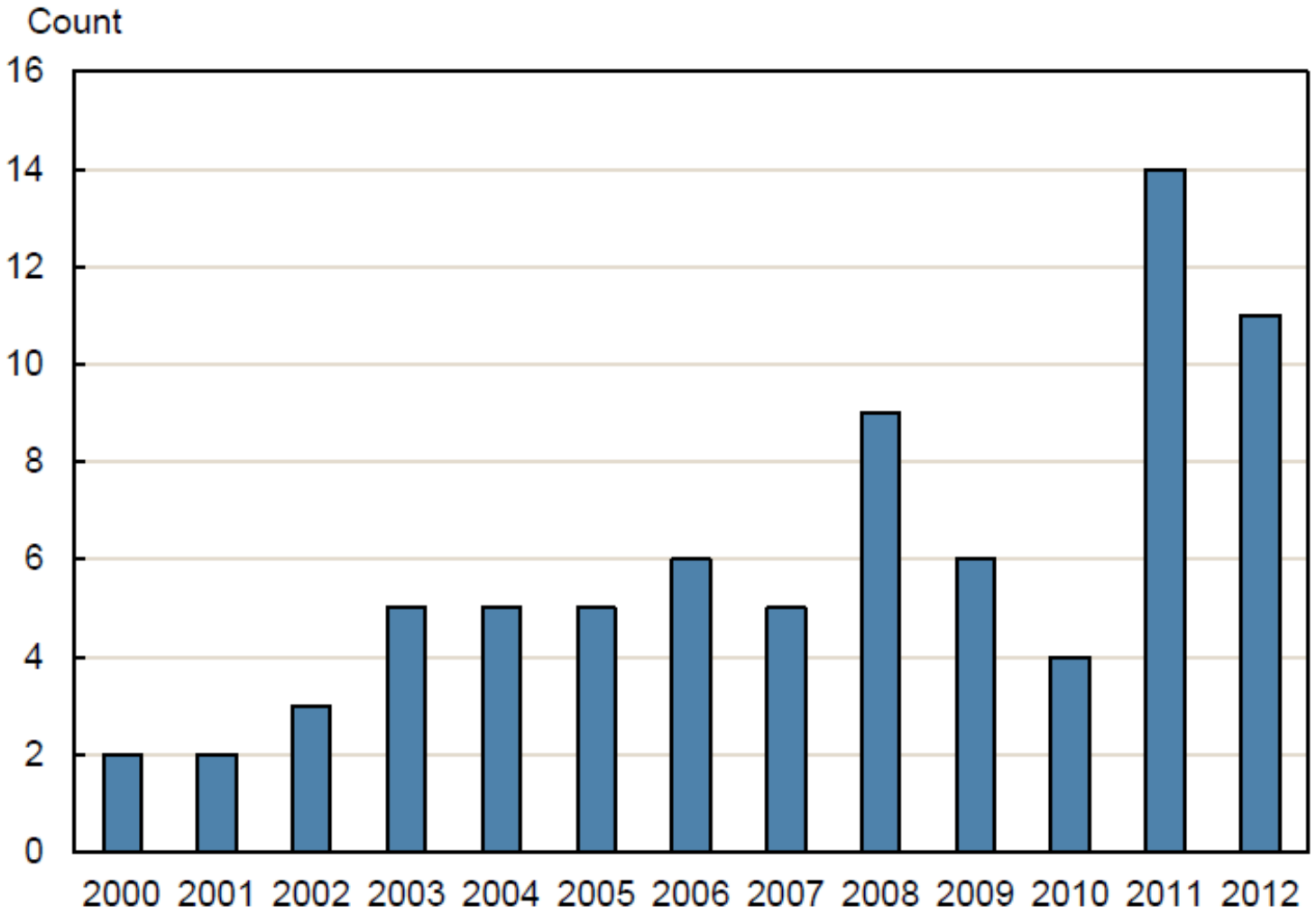
Presentation Overview

- Increasing Incidence and Severity of Natural Disasters
- How this Affects Transmission Planning
- PG&E Case Study and Nexant Survey
- Key Takeaways

Catastrophic Impacts of Hurricane Sandy

- Since Hurricane Sandy in 2012, improving grid resiliency has been the focus of many electric utility and government stakeholders
- Direct impacts
  - Estimated $65 billion in damages (2nd costliest hurricane to hit the U.S.)
  - Deaths of 72 people
  - Nearly 2 million customers without power for a week or more
- Indirectly led to the deaths of another 87 people, 50 of which were attributed to power outages
  - Numerous senior citizens without heat died from hypothermia
  - Other victims died of carbon monoxide poisoning due to improperly vented generators
- **Source:** Executive Office of the President. "Economic Benefits of Increasing Electric Grid Resilience to Weather Outages." August 2013.

Billion-Dollar Weather Disasters



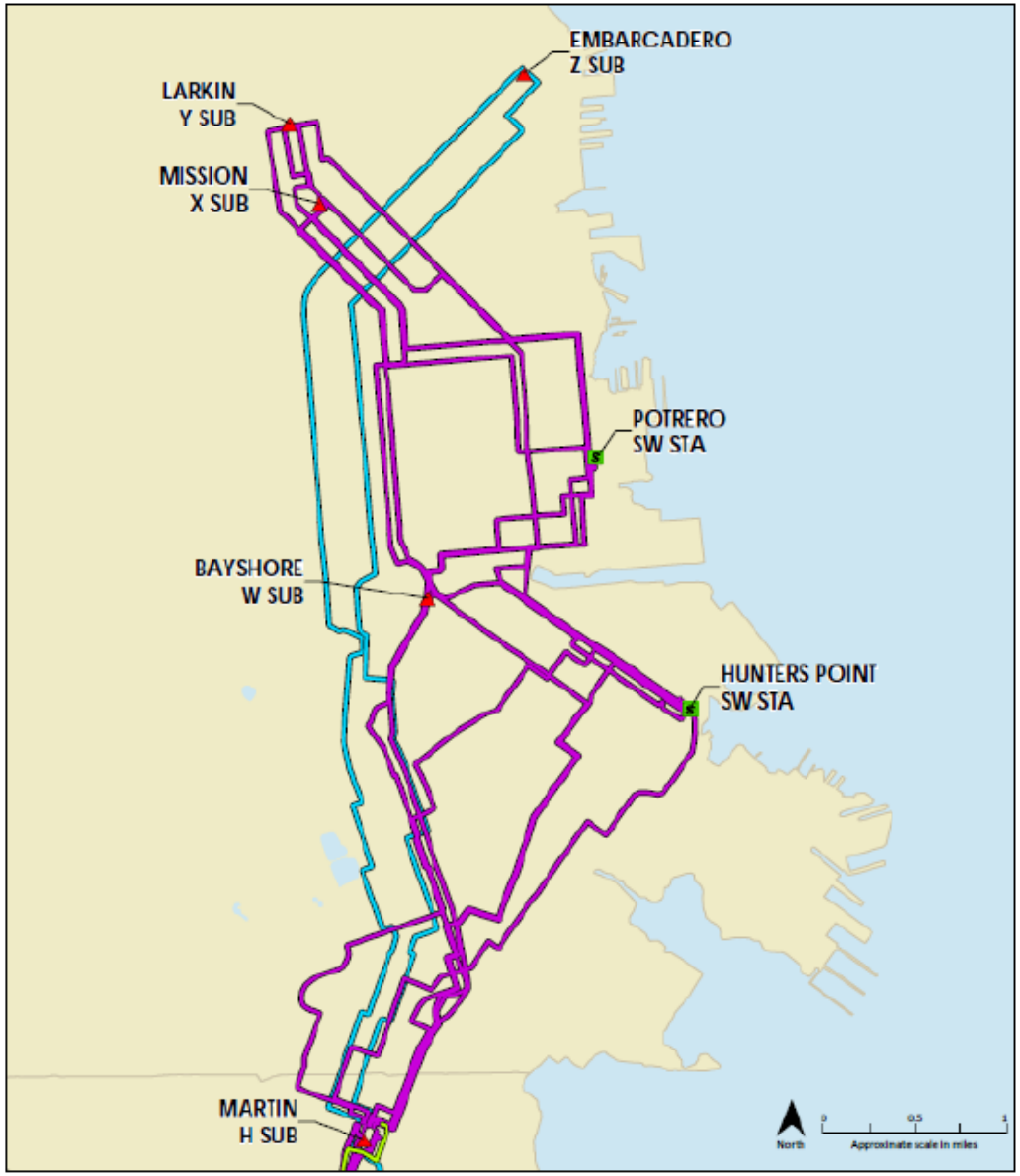
Source: Executive Office of the President. "Economic Benefits of Increasing Electric Grid Resilience to Weather Outages." August 2013.

- Since 1980, the United States has experienced 144 weather disasters with a damage cost over $1 billion
- Total cost of these 144 events exceeds $1 trillion
- Seven of the ten costliest storms in U.S. history occurred between 2004 and 2012
- Incidence and severity of extreme weather will continue to increase due to climate change

How Do the Increasing Incidence and Severity of Natural Disasters Affect Transmission Planning?

- Utilities must evaluate situations in which it is necessary to exceed usual NERC transmission reliability standards, based on the following considerations:
  - Future likelihood of a catastrophic natural disaster and how it would impact the transmission system
  - Areas impacted by natural disaster and potential transmission outages, especially key economic hubs
  - Potential for long duration power outages (24 hours to multiple weeks) and associated customer interruption costs
- Utilities must provide strong justification for transmission investments that exceed the usual standards, as demonstrated in a recent filing by Pacific Gas & Electric Co. (PG&E)

1st Consideration: Future Likelihood of a Catastrophic Natural Disaster and How it Would Impact the Transmission System



- Over the course of 20 years, the likelihood of a catastrophic earthquake in San Francisco is nearly certain
- For the Embarcadero substation in Downtown San Francisco, sole source of power is two underground, parallel 230 kV cables running 7 miles from Martin substation
- Considering that both lines cross the San Andreas fault, a catastrophic earthquake may take out both transmission lines

2nd Consideration: Areas Impacted by Natural Disaster and Potential Transmission Outages



3rd Consideration: Potential for Long Duration Power Outages and Associated Customer Interruption Costs

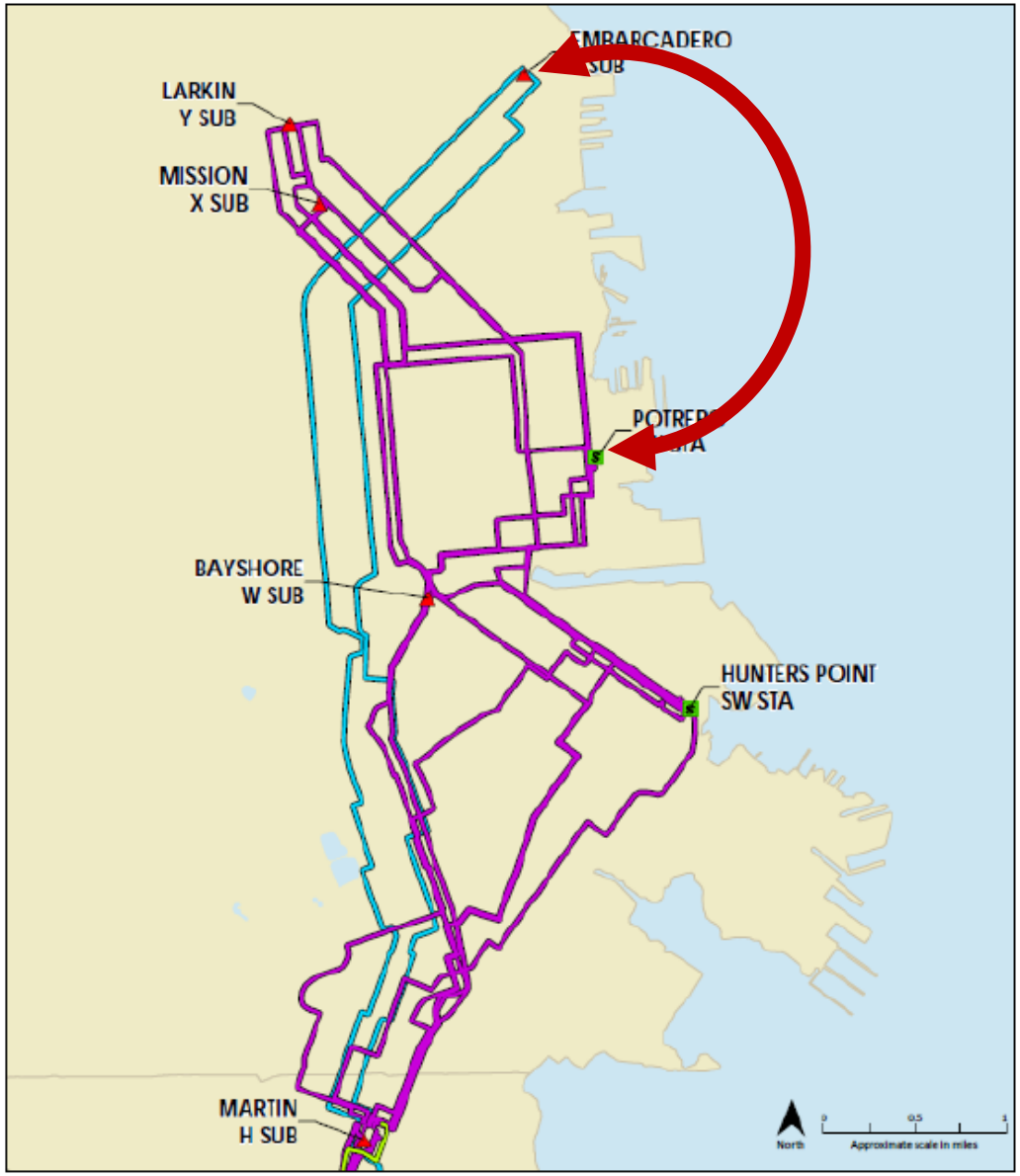
- If a catastrophic earthquake takes out both transmission lines, most of Downtown San Francisco would lose power for 24 hours to 7 weeks
- *In addition* to the damages that result from the natural disaster, customers experience substantial costs for each of these scenarios
  - How do we measure these direct costs?
  - How do these costs impact the broader economy?
  - What is the impact of these costs on employment?
- Nexant conducted a survey to estimate the direct costs that business customers would experience for each of these scenarios
- Indirect ("spillover") costs were estimated as a multiple of direct costs, based on regional economic modeling literature

3rd Consideration: Potential for Long Duration Power Outages and Associated Customer Interruption Costs (cont'd)

Outage Duration	Direct Cost ($ Billions)	Indirect Cost ($ Billions)	Total Outage Cost ($ Billions)
24 hours	$0.1	$0.1 to $0.3	$0.2 to $0.4
4 days	$0.4	$0.2 to $0.8	$0.6 to $1.2
3 weeks	$1.4	$0.7 to $2.8	$2.1 to $4.2
7 weeks	$2.9	$1.5 to $5.8	$4.4 to $8.7

- For a 3 to 7-week outage, the total cost ranged from $2.1 to $8.7 billion
- More than one out of 10 small/medium businesses report that they have a 70% or greater likelihood of going out of business as a result of an outage lasting 3 to 7 weeks
- For an outage lasting 3 to 7 weeks, businesses in each segment would stop paying around 35% or more of their contract/temporary employees on average
- Over 40% of part-time employees of small/medium businesses would not be paid throughout a 7-week outage
- For a 7-week outage, businesses would stop paying an average of 16% to 27% of their full-time employees (depending on segment)

Proposed Transmission Line Investment



- PG&E proposed to construct a $200 million transmission line that connects the Potrero substation to the Embacadero substation, through San Francisco Bay
  - New line would not cross the fault
- PG&E filed testimony that addressed the considerations described in this presentation, including Nexant's long duration outage cost study
- CPUC approved the investment without challenge or intervention, even though transmission service to the Embacadero substation already met NERC standards

Key Takeaways

- Incidence and severity of natural disasters are increasing
- Key economic hubs are increasingly at risk of long duration power outages that can cost customers billions of dollars, *in addition* to the damages that result from the natural disaster
- By measuring and understanding the customer interruption costs that result from these scenarios, utilities can provide strong justification for transmission investments that exceed the usual standards, as demonstrated by this case study
- Best method for estimating customer interruption costs is to conduct a survey of representative samples of customers in the area of interest

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