Enhancing Test Power Systems for Dynamic Cascading Outage Simulations

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Outline

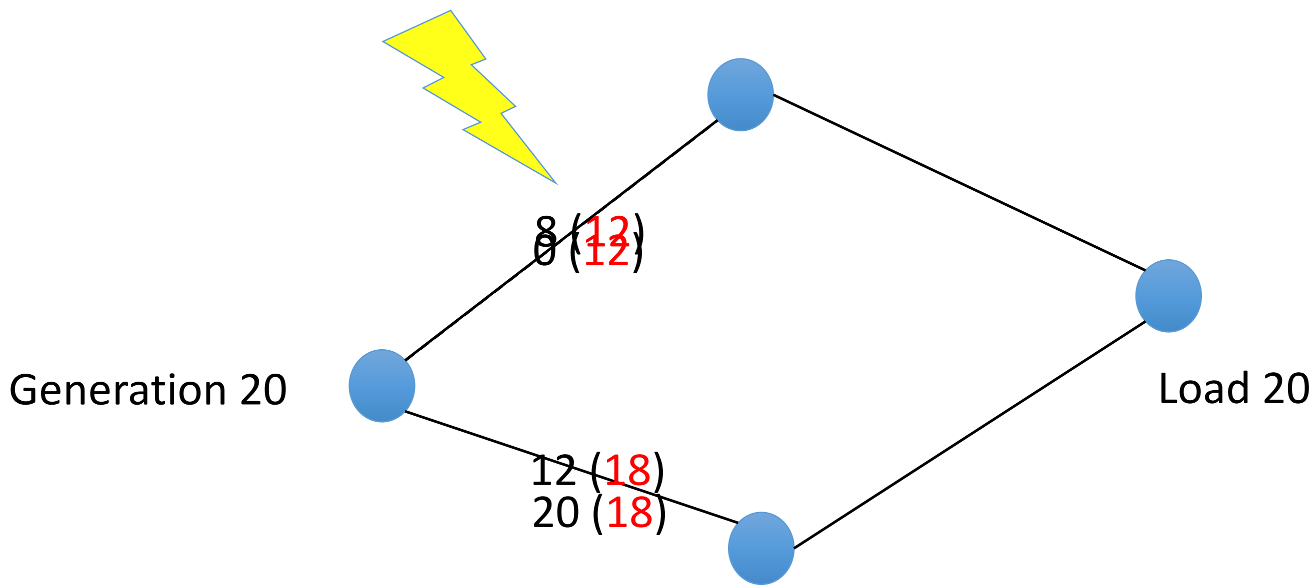
- **Introduction**
  - Cascading outages
  - Existing methodologies
  - Challenges of dynamic model
- Mechanisms of cascading outages
  - Why dynamic simulation?
  - Needed data
- The proposed standard systems
- Future work and conclusion

Introduction: cascading outages

- The contemporary power network is operated near its marginal limits.

- Definition by NERC: “uncontrolled loss of any system facilities or load, whether because of thermal overload, voltage collapse, or loss of synchronism, except those occurring as a result of fault isolation”.

Introduction: cascading outages



Normal operation

One line is tripped

Power flow reroute

Exceeds the limit

Trip the second line or reduce load

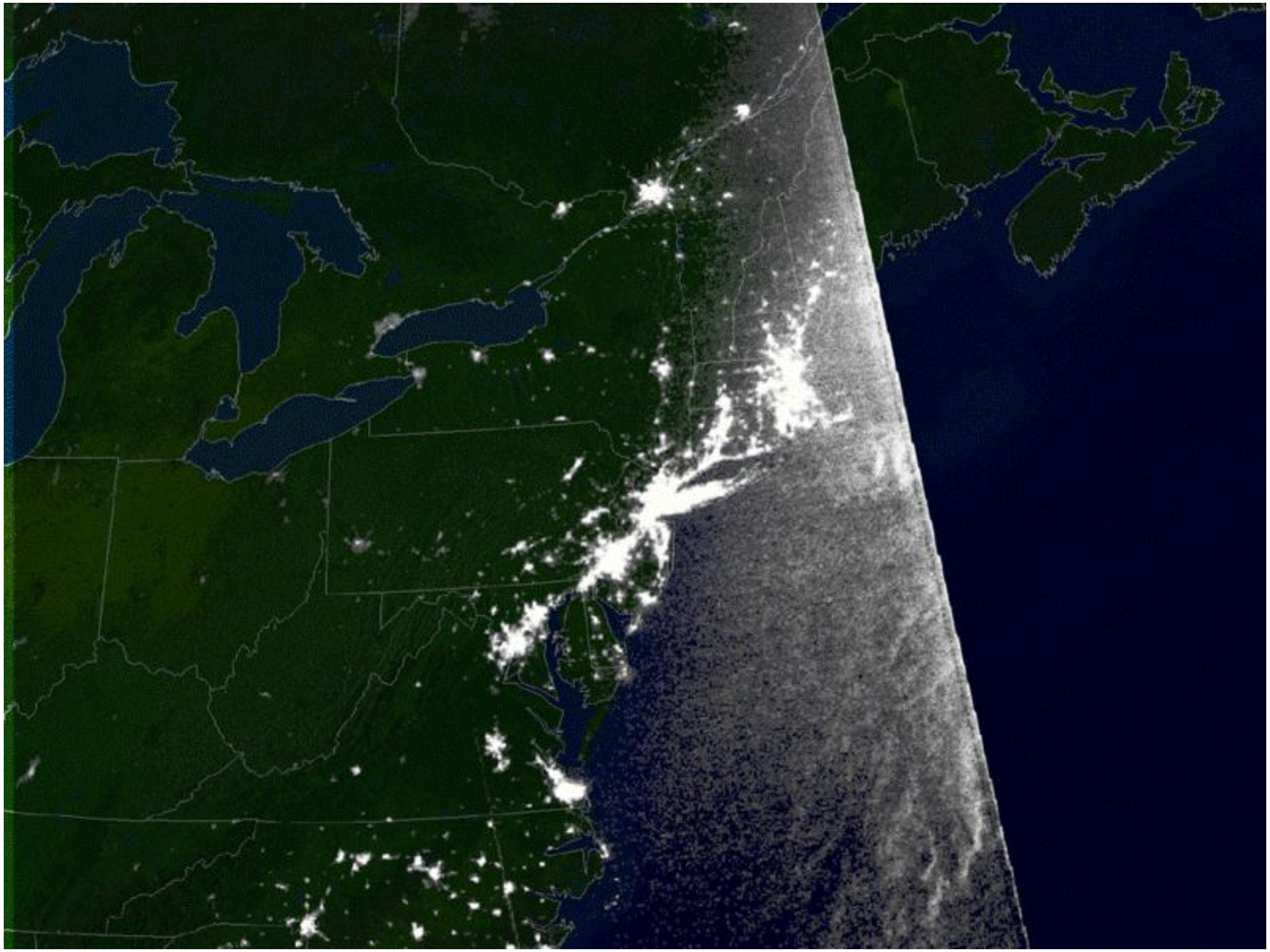
Introduction: cascading outages

- Main reason for large blackouts
- Impacts
  - The amount of power that being taken away and the amount of people are un-served caused by the event.
  - e.g., July 30-31 2012 in India, 32 GW of generating capacity was taken off line, which affected over 620 million people.

- Are cascading outages or large blackouts going to happen again?

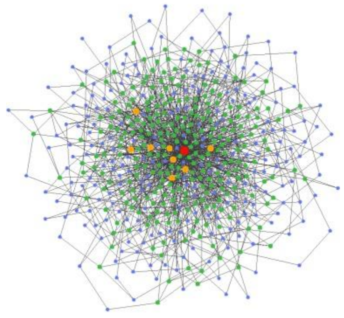
Introduction: cascading outages

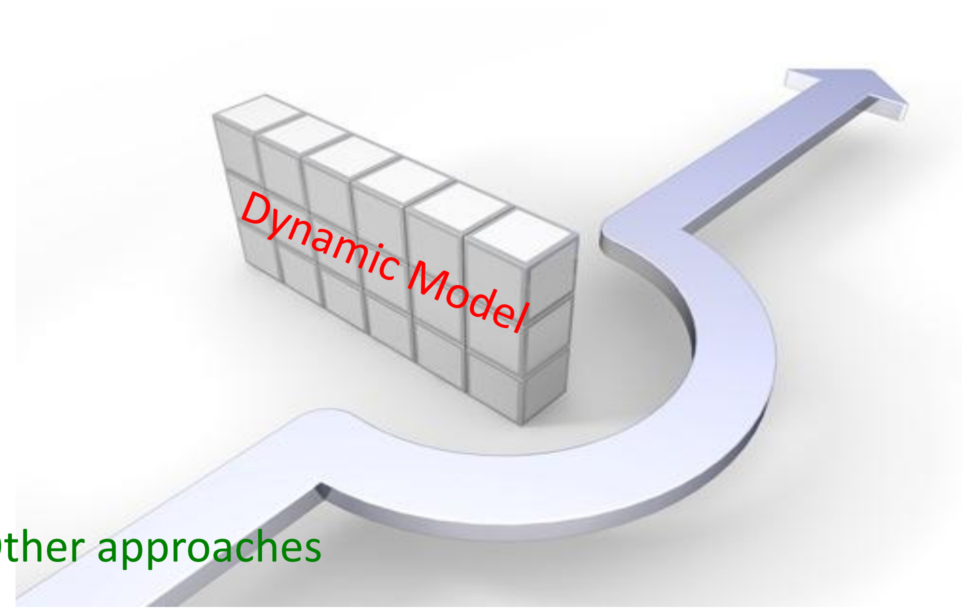
Satellite image before and after the blackouts, 2003 North America



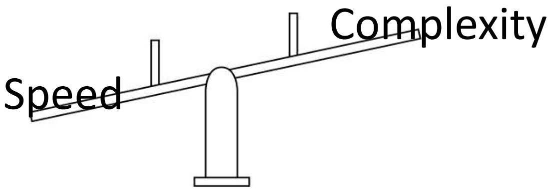
Introduction: methodologies

- Contingency analysis
  - Steady state or quasi-steady state model
  - High level probabilistic model
  - Modern techniques (e.g., graph theory, PMU, HPC)
  - Dynamic model

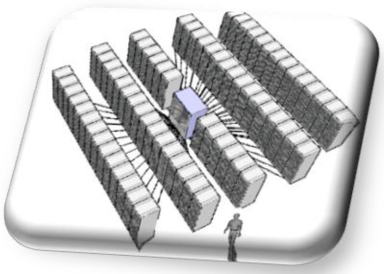




Introduction: challenges



- N-x contingency
  - Screening techniques
  - HPC and parallel computing
- Dynamic models complexity
  - Use generic models
- Algorithmic complexity
  - Better numerical methodology
- <u>Limited access to dynamic data</u>
  - ‘Fingers crossed’



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- **Mechanisms**
  - Why dynamic simulation?
  - Needed data
- The proposed systems
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Mechanisms

- Failure of the overloaded branches by over-current protections (e.g., 2003 Italian and NE America)
- Failure of the overloaded branches by distance protections (e.g., 2003 NE America and SE Canada)
- Thermal failures of overloaded branches (e.g., 2003 NE America)
- Voltage instability
- Frequency instability (e.g., 2003 Italian, 2006 Europe)
- Transient angular instability
- Small-disturbance angular instability (e.g., 1996 WSCC)
- Unwanted trips due to hidden failures (e.g., 1996 WSCC)

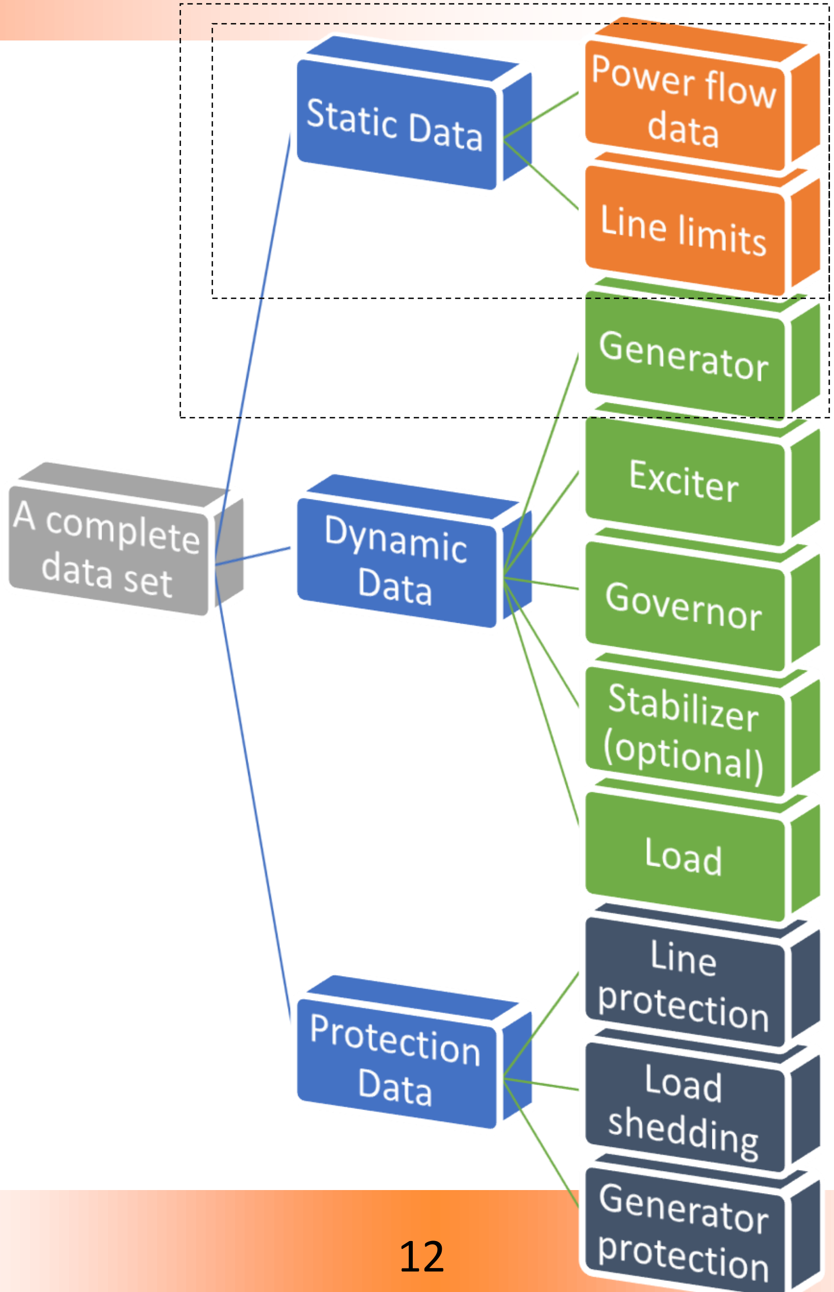
Mechanisms: why dynamic model

- Modeling environment

Mechanism	Model
Branch outages by OC & DIST relays	Static / Dynamic
Branch outages by thermal failures	Static / Dynamic
Voltage instability	Static / Dynamic
Frequency instability	Dynamic
Transient angular instability	Dynamic
Small disturbance angular instability	Dynamic
Unwanted trips due to hidden failures	Static / Dynamic

- Dynamic model is salient

Mechanisms: needed data



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Proposed systems

THE ORIGINAL GENERAL INFORMATION OF THE PROPOSED DYNAMIC TEST SYSTEMS

Test Case \ Info.	Number of buses	Number of branches	Number of generators	Number of loads	Line ratings	Dynamic data	Protection data
IEEE 9 Bus [8]	9	9	3	6	Yes	Yes (Partial)[1]	No
Kundur's 2-Area [9]	15	12	4	2	No	Yes (Partial)[1]	No
IEEE 39 Bus [10]	39	46	10	19	Yes	Yes (Partial)[1]	No
5-Area 68 Bus [11]	68	87	16	53	No	Yes (Partial)[1]	No
IEEE 3-Area RTS [12]	73	120	99	60	Yes	Yes (Partial)[1]	No

1: Partial — only a limited set of dynamic data are available (e.g., data for machine dynamics is included but no data for exciter, governor and load.)

- Cascading outage study requires large systems
- Small system such as 9-bus system is more suitable for model validation
- This initial study starts with relatively small cases to ensure the maturity and fidelity of our approach

Proposed systems

- For example:

  Exciter --- IEEE AC4A or modified model

  Governor --- IEEE TGOV1 or other generic models

  Load --- ZIPE or adapted generic dynamic load model

- Parameters

  Computed based on the existing information and additional rules

Proposed systems

Protection relays

- Line protection:
  - Over-current relay
  - Distance relay
- Generator protection (not always included):
  - Under-frequency
  - Under-voltage
  - Over-excitation
- Load shedding:
  - Under-voltage load shedding
  - Under-frequency load shedding

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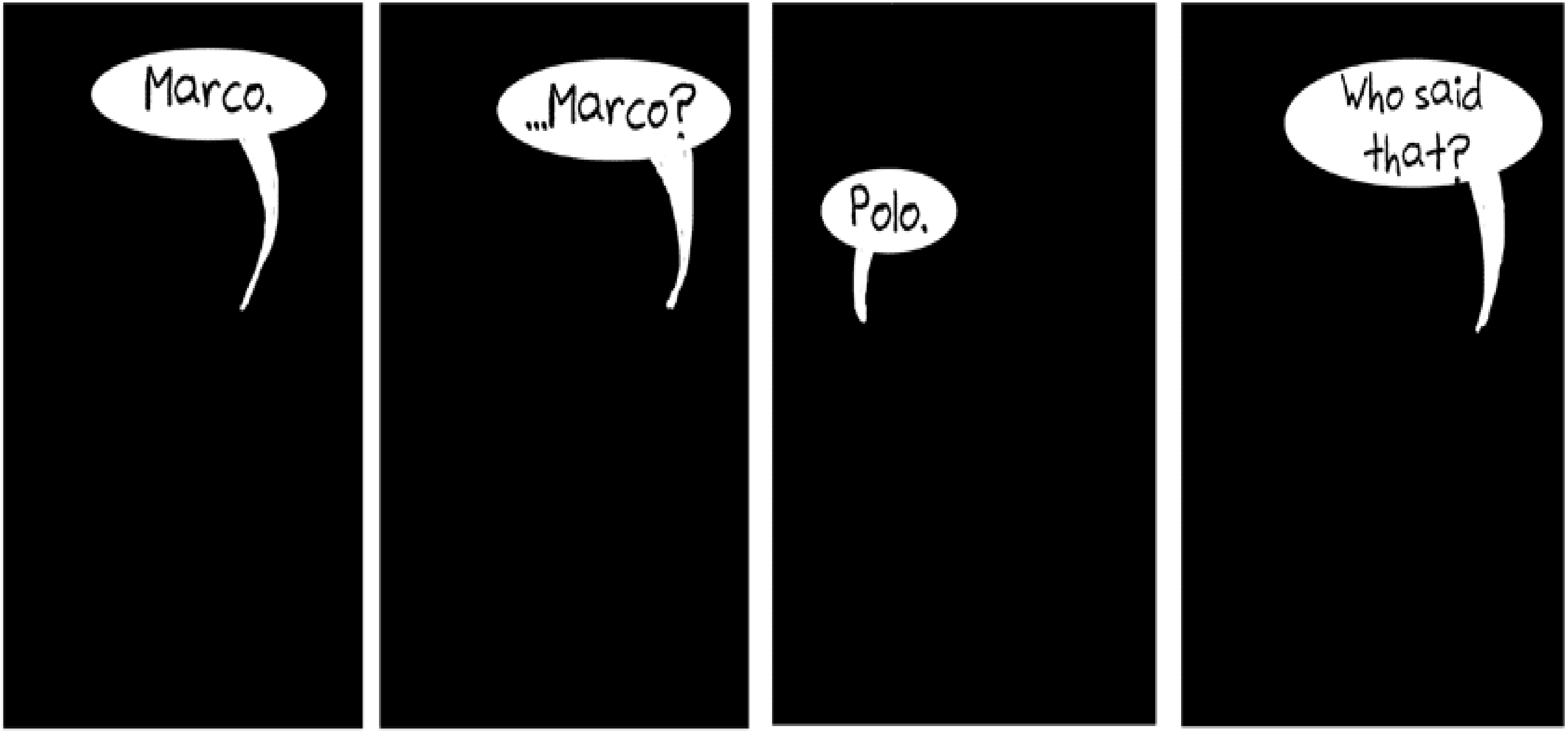
Conclusion

- Discussed the need of dynamic data
- Proposed a small set of test systems as standard cases (available in our test system archive)
- It is useful to homogenize and advance dynamic simulations for the study of cascading outages from the stability and protection perspective
- Publish more test systems by systematically generating dynamic data and protection data


Marco.
...Marco?
Polo.
Who said that?

Thank you for your attention!

Questions?