Risk Assessment of Cascading Failures in Power Systems with High Renewable Penetration

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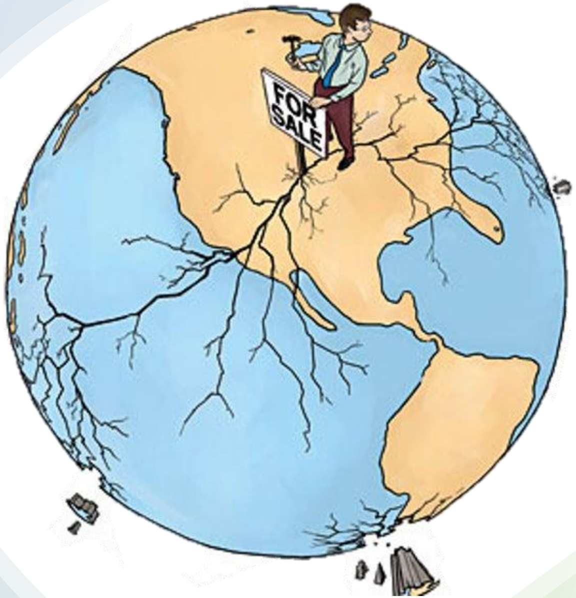
The author acknowledges financial support from EPSRC (EP/L016141/1) through the Power Networks Centre for Doctoral Training.

Cascading Failures

The uncontrolled successive loss of bulk electric system facilities triggered by an incident (or condition) at any location.



Source: https://www.nerc.com/files/glossary_of_terms.pdf

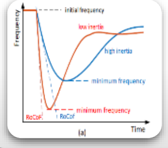
Cascading Failure Models

★★★ DC power flow based QSS models

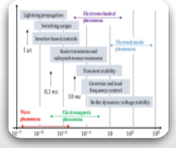
- Reliably converge and computationally fast
- Capture line overload and re-dispatch capabilities
- Show acceptable consistency with historical data

- Neglect voltage deviations and reactive power flows
- Neglect transient dynamics following events

Need for a Dynamic Cascading Failure Model



Low inertia issues



Distinct timescales of system dynamics

Emerging techniques

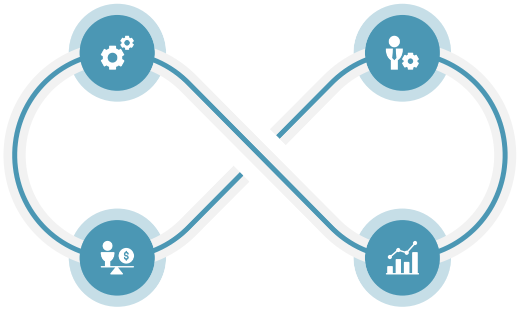
Need to re-think the assumptions in QSS models

Increasing need for a time-based dynamic cascading failure model

Background requirements

Modelling of renewable generators

Generation dispatch methods



Ancillary services, e.g., frequency containment

Transmission expansion planning

Dynamic Cascading Failure Simulator

Focus on frequency-related dynamics

Protection

- SG: over-/under-frequency relay [-5%/+3%] and an out-of-step relay
- DFIG: UVRT capability and an over-/under-frequency relay [-5%/+3%]
- Transmission line thermal Protection
- Under-frequency load shedding

Software

DIgSILENT PowerFactory via Python API

SGs

- Classical 2nd-order model
- Primary and secondary frequency control

Fast frequency responses

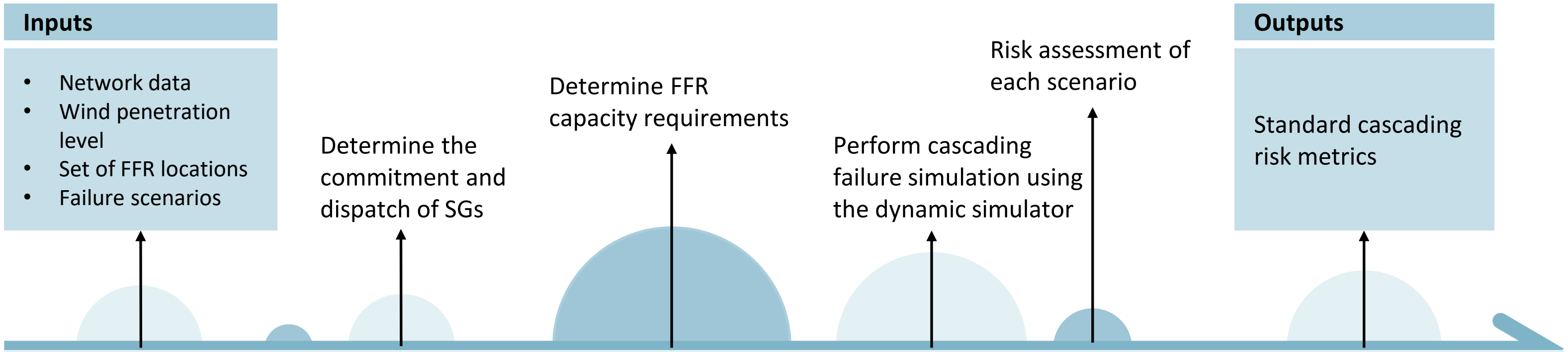
- Provided by energy storage systems
- Frequency regulation follows an P-f droop control

Wind Generator

- Type 3 model, i.e., DFIG
- Frequency response
- Fault ride through capability

Source: https://github.com/YitianDai/Dynamic-cascading-failure-simulator

Framework for Assessing Cascading Risk in Renewable-rich Grids



- Applicable to any test system suitable for dynamic cascading failure study

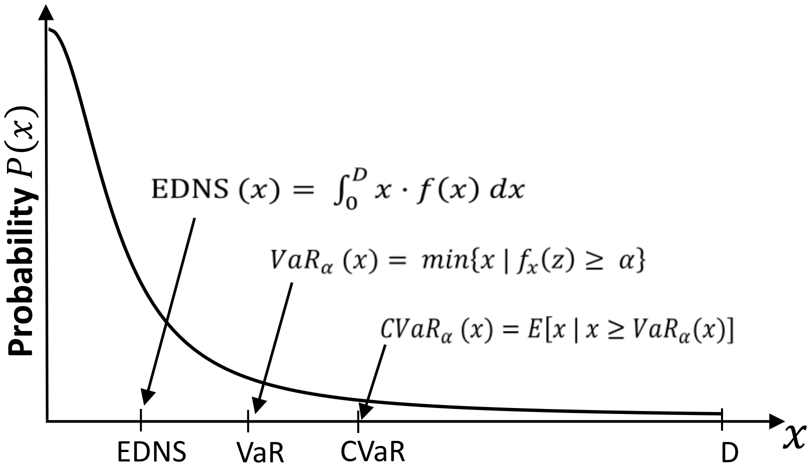
Case Study Application

Test System	Wind Penetration	Failure Scenarios
Illinois 200-bus synthetic system	Increased from 10% to 60%	1000 N-2 contingencies

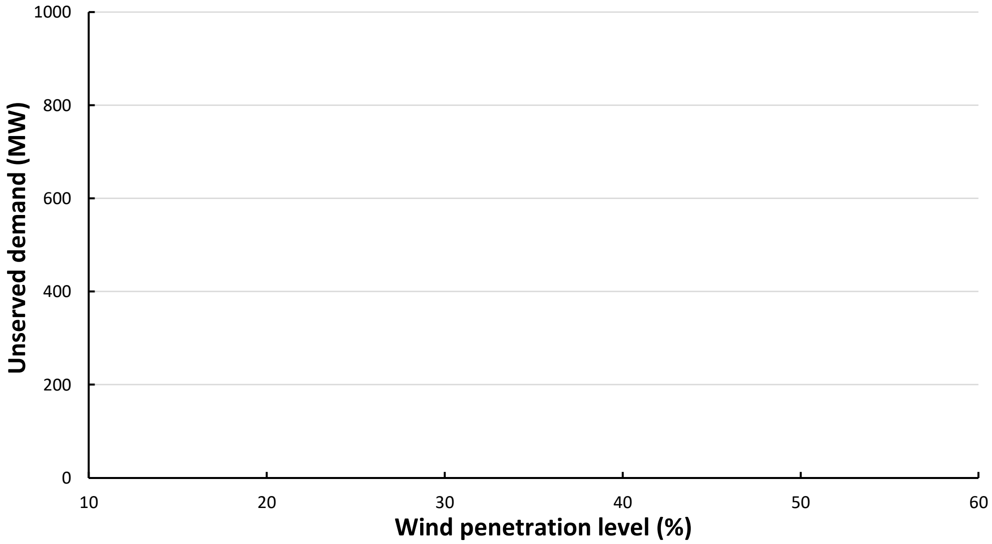
Cascading Risk Metrics

Amount of Unserved Demand

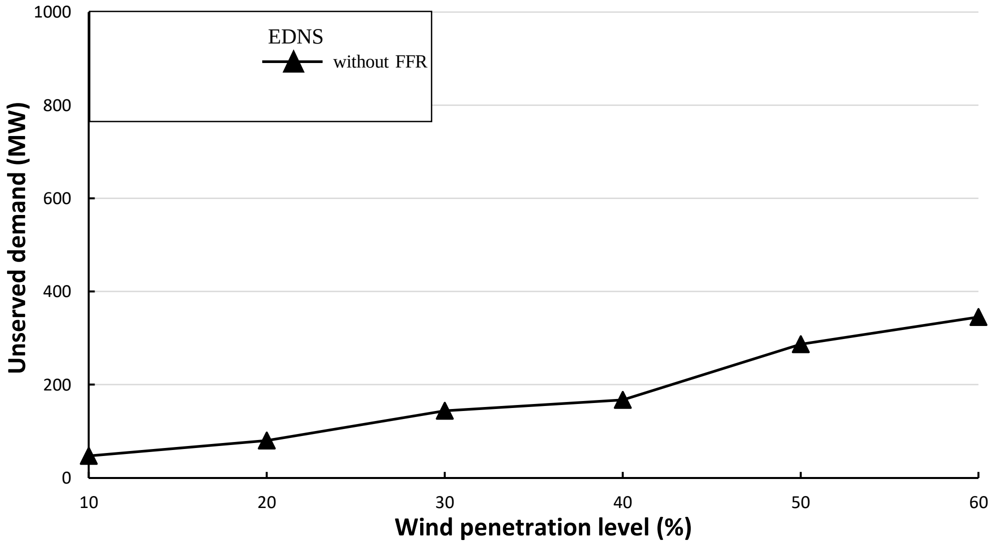
1) Expected Demand not Served (EDNS)
2) Value at Risk (VaR)
3) Conditional Value at Risk (CVaR)



Increased Wind Penetration vs. Cascading Risk

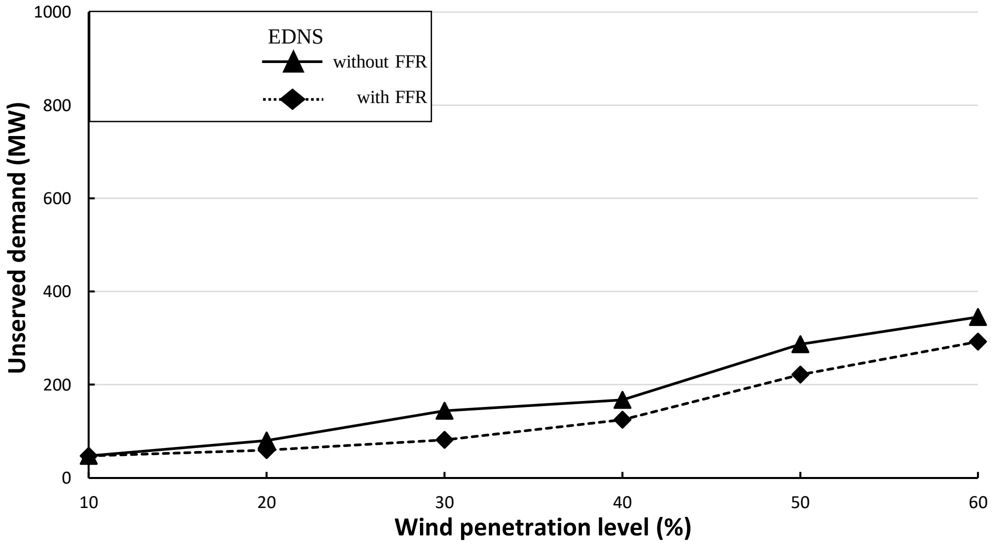


Increased Wind Penetration vs. Cascading Risk



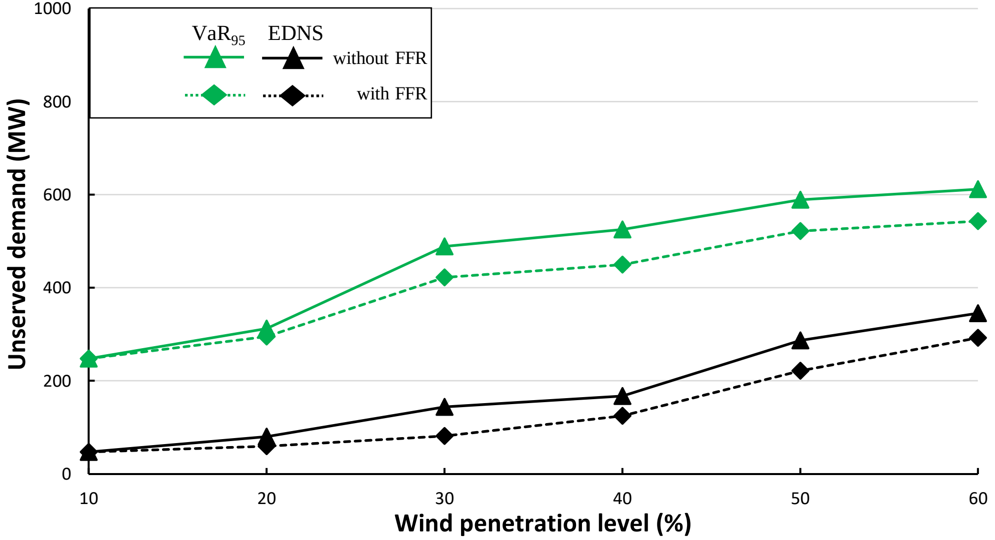
- Positive correlation between cascading risk and wind penetration.

Increased Wind Penetration vs. Cascading Risk



- Positive correlation between cascading risk and wind penetration.
- Mitigated with the inclusion of FFR

Increased Wind Penetration vs. Cascading Risk



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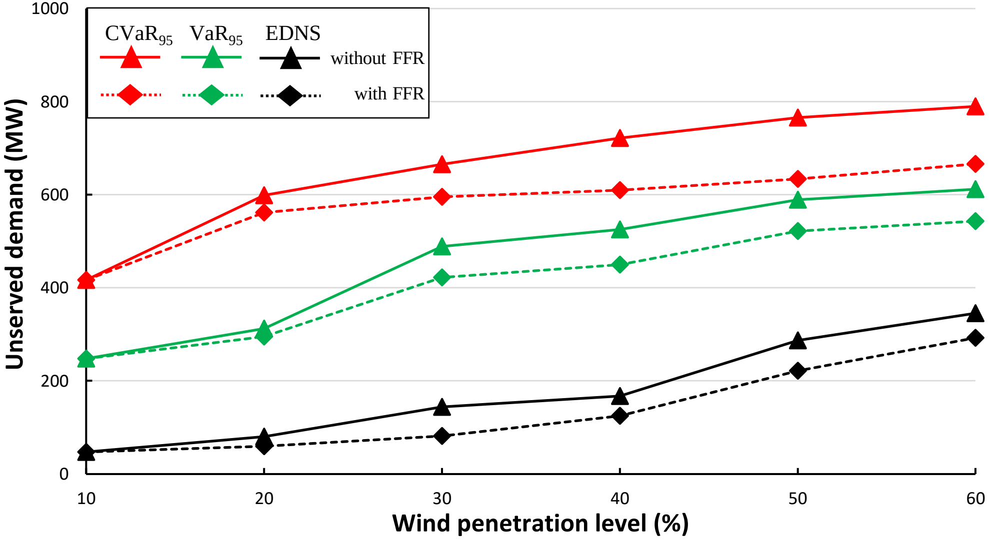
Increased Wind Penetration vs. Cascading Risk



- Positive correlation between cascading risk and wind penetration.
- Mitigated with the inclusion of FFR

- FFR plays an important role in mitigating cascading risk in severe cases
- Especially at high wind penetrations.

Conclusions

- Emphasized the importance of accurate modelling of system dynamics in cascading failure analysis.
- Quantified the impact of increased wind penetration on cascading failures by standard risk metrics.
- Proposed a criterion for determining FFR capacity requirements, and investigated the impacts of FFRs on cascading risks.
- Future work will focus on transforming analytical findings into informed mitigation strategies.

Thank you!

Any questions?

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