EST 1892 LSBU

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UNIVERSITY OF SUSSEX

Validated model of AC Cascading Failure Model (AC-CFM) for real-time environments

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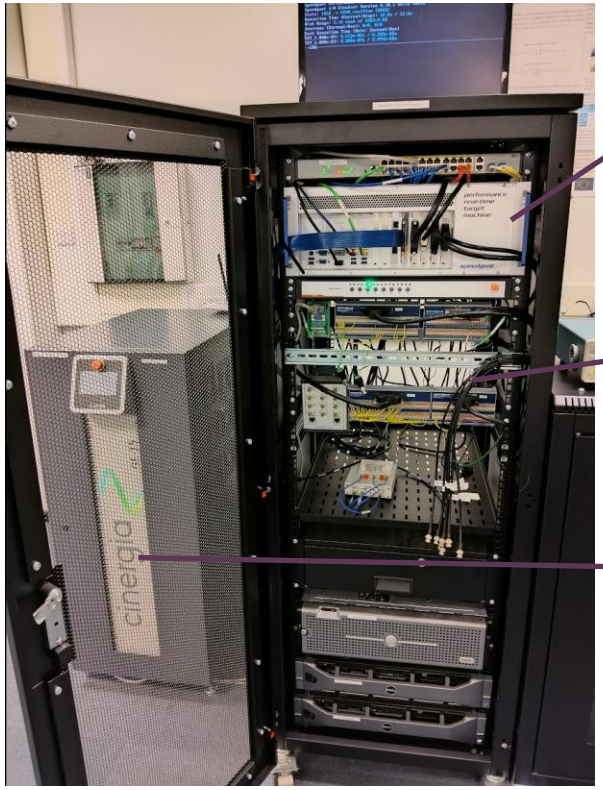
Introduction

- A real-time hardware-capable dynamic implementation of the AC-CFM method
- Multi-vendor real-time power systems labs
- Initiative supported by OPAL-RT with licenses and technical guidance
- Proof-of-concept funded by UKRI GCPB Network+ project (www.greenconnectedbritain.org)
- Liaison with AC-CFM co-author



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Speedgoat™ real-time target

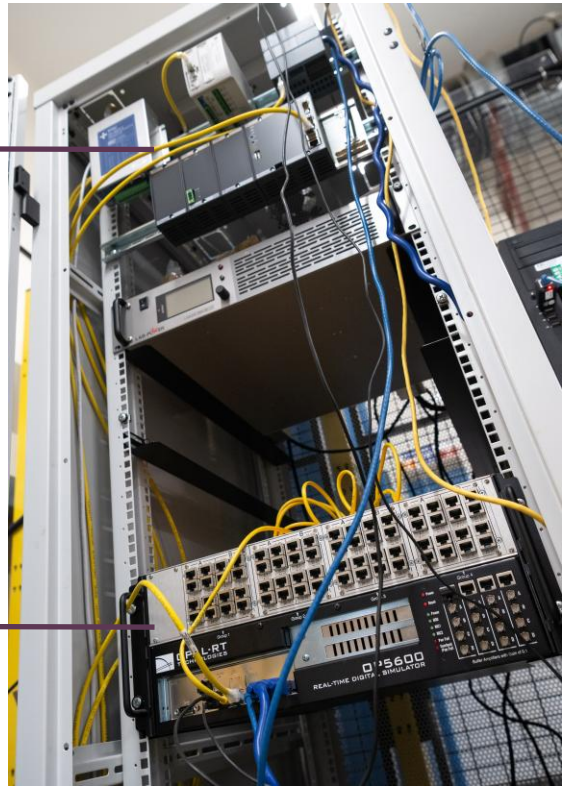
Analogue / digital / comms breakouts

Four quadrant amplifier

UoS

PAC/PLC controllers

OPAL-RT real-time target



Motivation

AC Cascading Failure Model (AC-CFM) - Quasi-Steady State (QSS)

Pros	Cons
Matpower casefile inputs	Lacks dynamics (e.g. frequency, protection)
Fast	Non-real-time
Widely cited	
Graphical & text log results	

Real-Time Phasor Implementation of AC-CFM Cascade Model

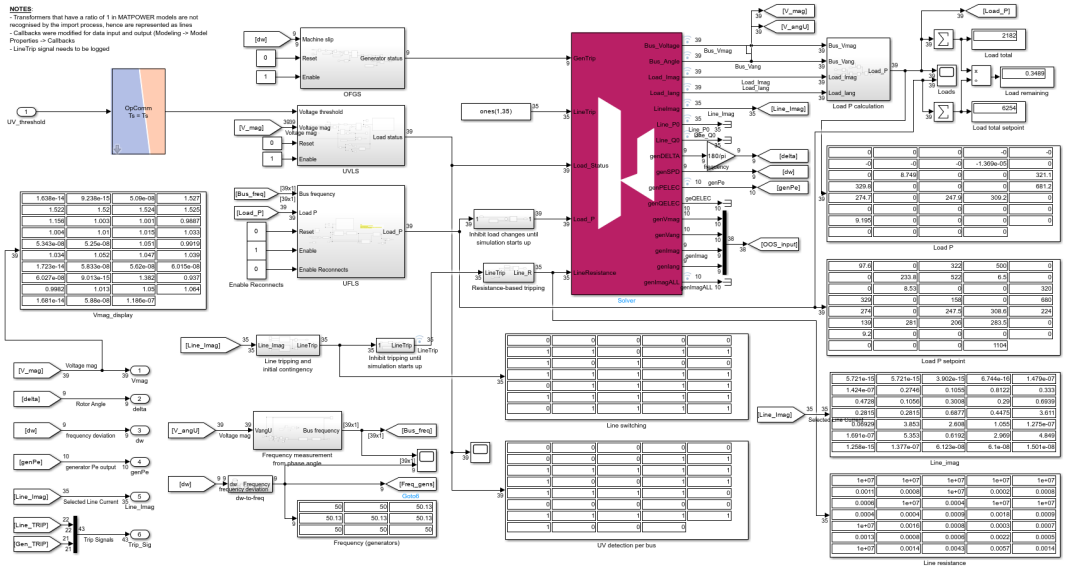
- Generalised dynamic and real-time version of AC-CFM for the research community
- OPAL-RT ePHASORSIM - dynamic phasor simulation
- Electrical machines, protection relays, grid connections with inertia
- Individual buses requiring higher fidelity modelling (e.g. GFM inverter / HVDC link) outsourced to separate Speedgoat targets
- Interfaced to real-world equipment e.g. measurement instruments, relays
- Communicate with emulated real-time flexibility services e.g. DSR aggregators

Proposed Solution

Validation Process

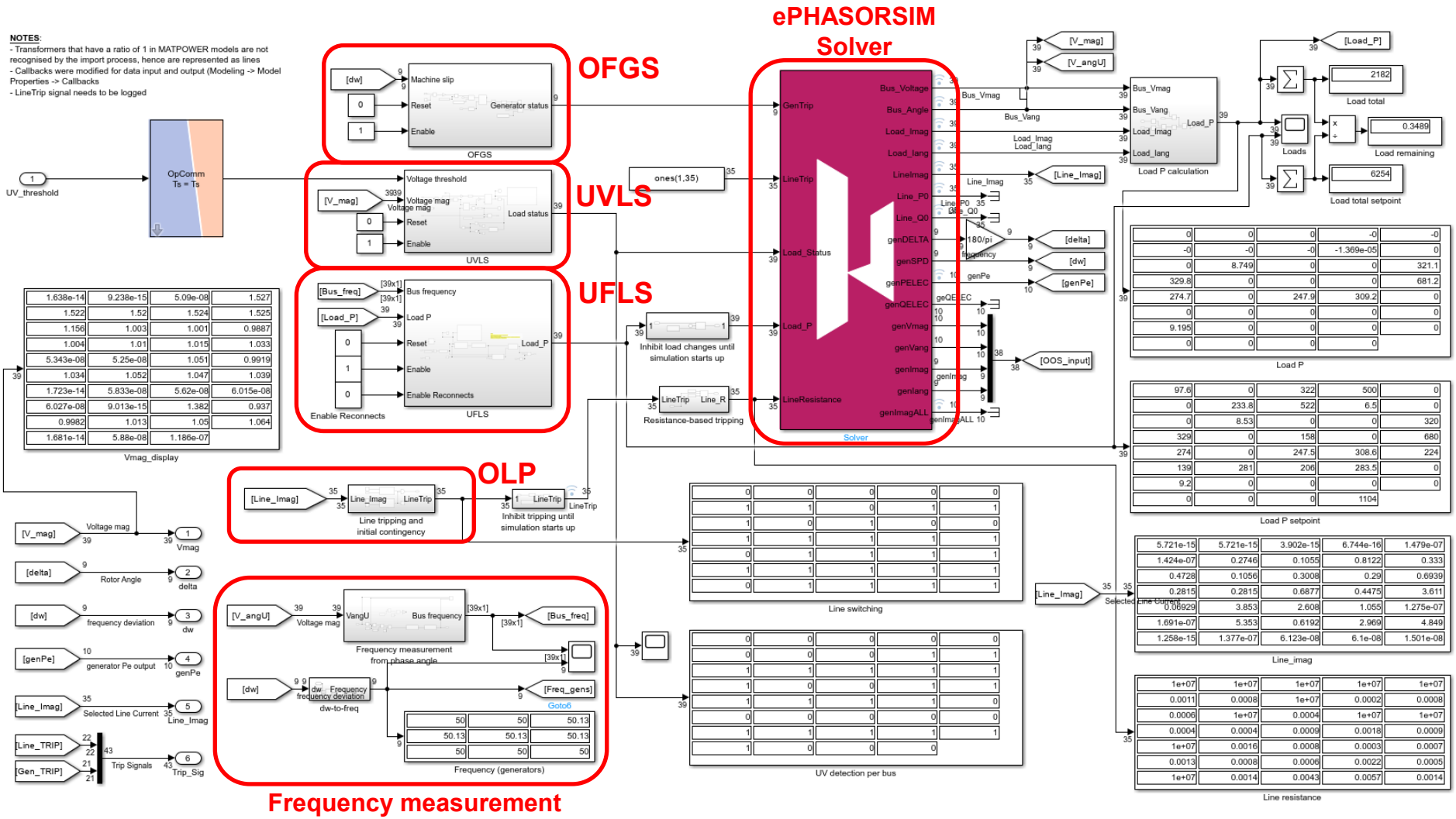
Ingest Matpower casefile w/ Pandapower → Run single-shot loadflow for initial conditions → Convert network to ePHASORSIM Excel format → Iterate through initial contingencies using Matlab LiveScript which calls Simulink model → Export results in .mat format and postprocess for validation in Jupyter Notebook

Simulink – ePHASORSIM Model



Proposed Solution

Simulink – ePHASORSIM Model



Challenges

QSS *[vs]* Dynamic modelling

Frequency measurements in phasor simulations

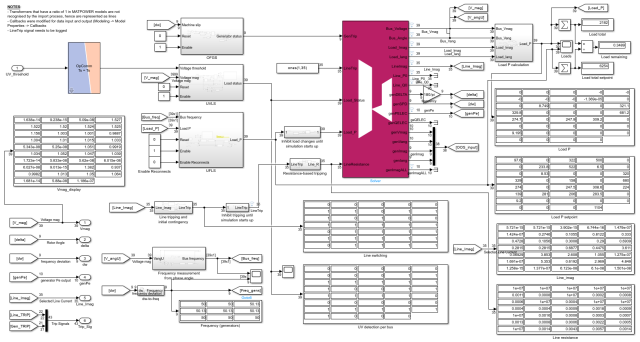
Line Tripping *[vs]* Line Impedance Modification

Line ratings

Other unknowns (e.g. machine dynamics)

Algorithms (e.g. load shedding)

Results validation / divergence



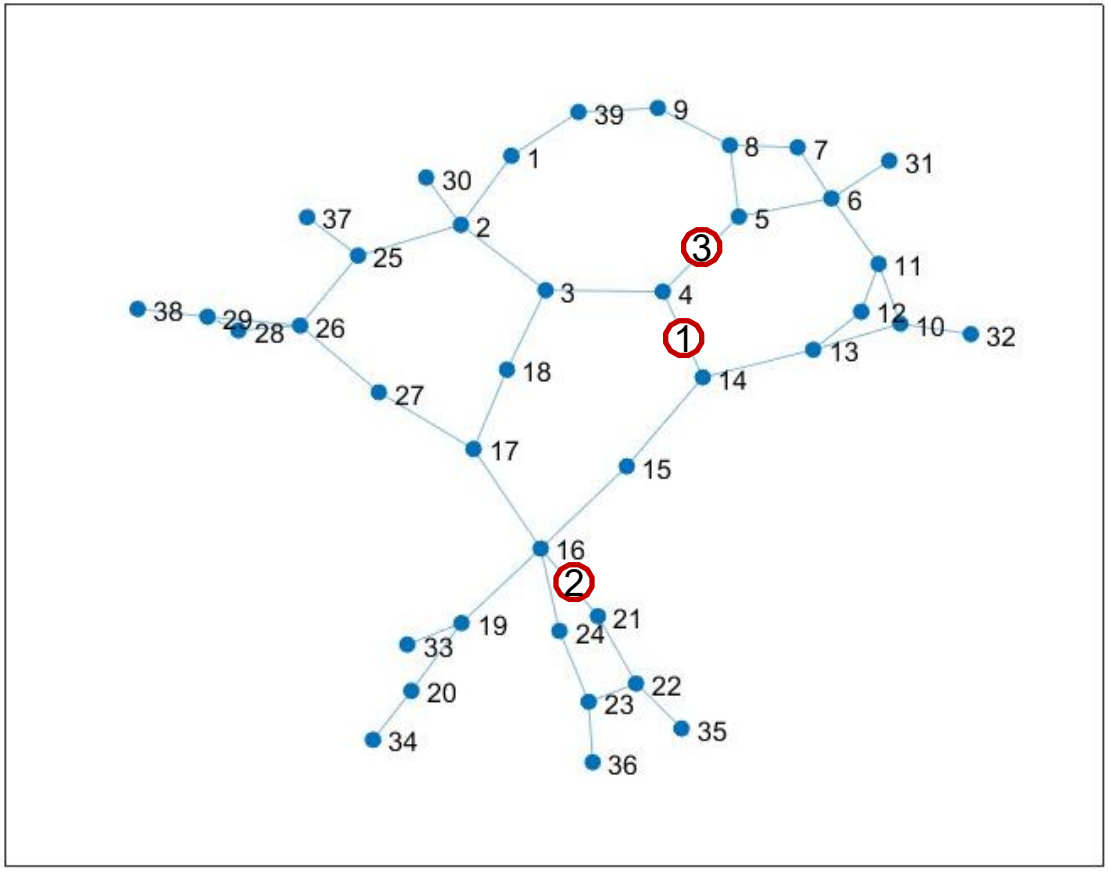
Case Study – IEEE 39-bus system

Initial Contingencies:

① **Contingency 1**: line between buses 4 and 14

② **Contingency 2**: line between buses 16 and 21

③ **Contingency 3**: line between buses 4 and 5 *(no cascade)*

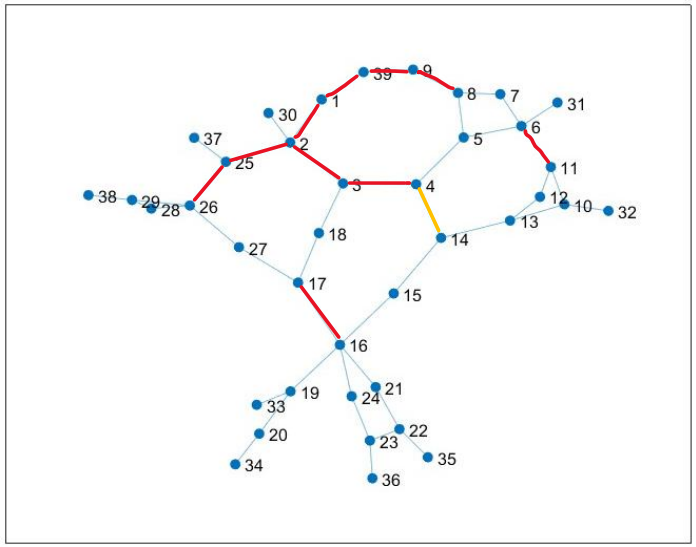


Results – Contingency 1 (line 4-14)

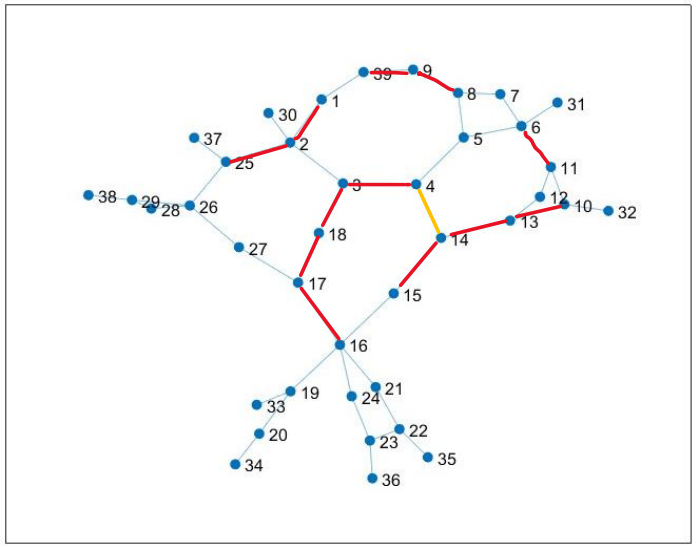
	Outages		Trip order	
(Bus from-to)	Our model	AC-CFM	Our model	AC-CFM
Line 1 to 2	Trip	Trip	5	4
Line 1 to 39	Trip	OK	5	
Line 2 to 3	Trip	OK	4	
Line 2 to 25	Trip	Trip	5	5
Line 3 to 4	Trip	Trip	3	3
Line 3 to 18	OK	Trip		3
Line 4 to 5	OK	OK		
Line 4 to 14	Trip	Trip	1	1
Line 5 to 6	OK	OK		
Line 5 to 8	OK	OK		
Line 6 to 7	OK	OK		
Line 6 to 11	Trip	Trip	2	2
Line 7 to 8	OK	OK		
Line 8 to 9	Trip	Trip	5	4
Line 9 to 39	Trip	Trip	5	4
Line 10 to 11	OK	OK		
Line 10 to 13	OK	Trip		3
Line 13 to 14	OK	Trip		3
Line 14 to 15	OK	Trip		3
Line 15 to 16	OK	OK		
Line 16 to 17	Trip	Trip	3	3
Line 16 to 19	OK	OK		
Line 16 to 21	OK	OK		
Line 16 to 24	OK	OK		
Line 17 to 18	OK	Trip		3
Line 17 to 27	OK	OK		
Line 21 to 22	OK	OK		
Line 22 to 23	OK	OK		
Line 23 to 24	OK	OK		
Line 23 to 36	OK	OK		
Line 25 to 26	Trip	OK	5	
Line 26 to 27	OK	OK		
Line 26 to 28	OK	OK		
Line 26 to 29	OK	OK		
Line 28 to 29	OK	OK		

Contingency 1
Lines tripped due to OLP

Our model:
Total shedding = 65%



AC-CFM:
Total shedding = 45%

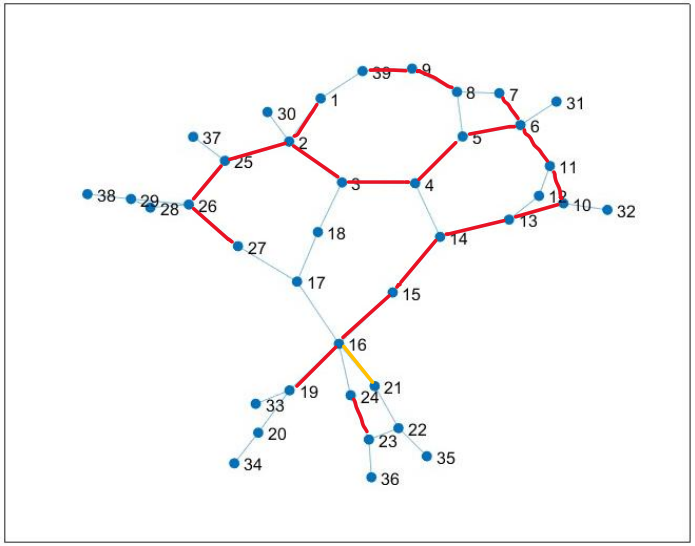


Results – Contingency 2 (line 16-21)

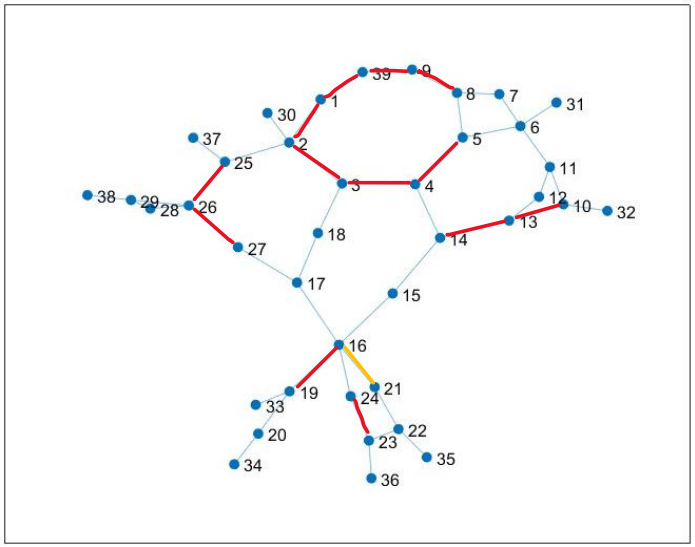
	Outages		Trip order	
(Bus from-to)	Our model	AC-CFM	Our model	AC-CFM
Line 1 to 2	Trip	Trip	5	5
Line 1 to 39	OK	Trip		5
Line 2 to 3	Trip	Trip	5	3
Line 2 to 25	Trip	OK	5	
Line 3 to 4	Trip	Trip	4	5
Line 3 to 18	OK	OK		
Line 4 to 5	Trip	Trip	4	5
Line 4 to 14	OK	OK		
Line 5 to 6	Trip	OK	5	
Line 5 to 8	OK	OK		
Line 6 to 7	Trip	OK	5	
Line 6 to 11	Trip	OK	4	
Line 7 to 8	OK	OK		
Line 8 to 9	Trip	Trip	5	5
Line 9 to 39	Trip	Trip	5	5
Line 10 to 11	Trip	OK	5	
Line 10 to 13	Trip	Trip	5	5
Line 13 to 14	Trip	Trip	5	5
Line 14 to 15	Trip	OK	5	
Line 15 to 16	Trip	OK	5	
Line 16 to 17	OK	OK		
Line 16 to 19	Trip	Trip	3	5
Line 16 to 21	Trip	Trip	1	1
Line 16 to 24	OK	OK		
Line 17 to 18	OK	OK		
Line 17 to 27	OK	OK		
Line 21 to 22	OK	OK		
Line 22 to 23	OK	OK		
Line 23 to 24	Trip	Trip	2	2
Line 23 to 36	OK	OK		
Line 25 to 26	Trip	Trip	5	4
Line 26 to 27	Trip	Trip	5	4
Line 26 to 28	OK	OK		
Line 26 to 29	OK	OK		
Line 28 to 29	OK	OK		

Contingency 2
Lines tripped due to OLP

Our model:
Total shedding = 99.9%

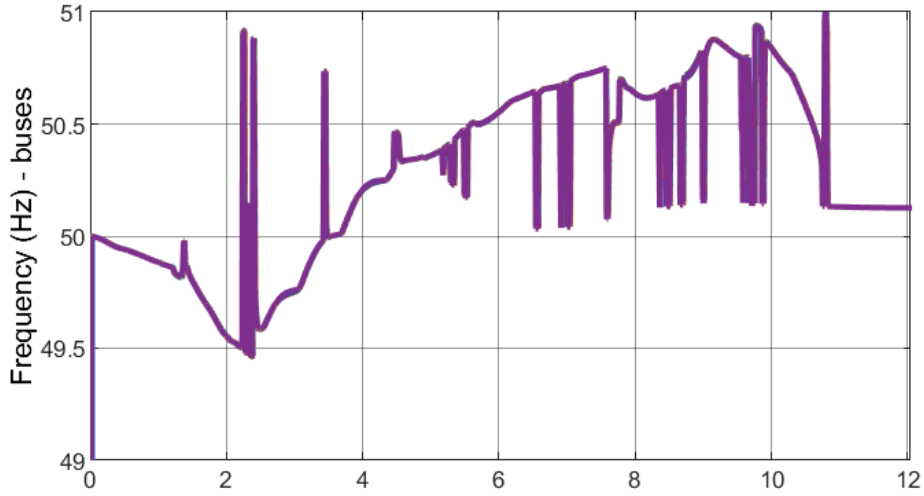


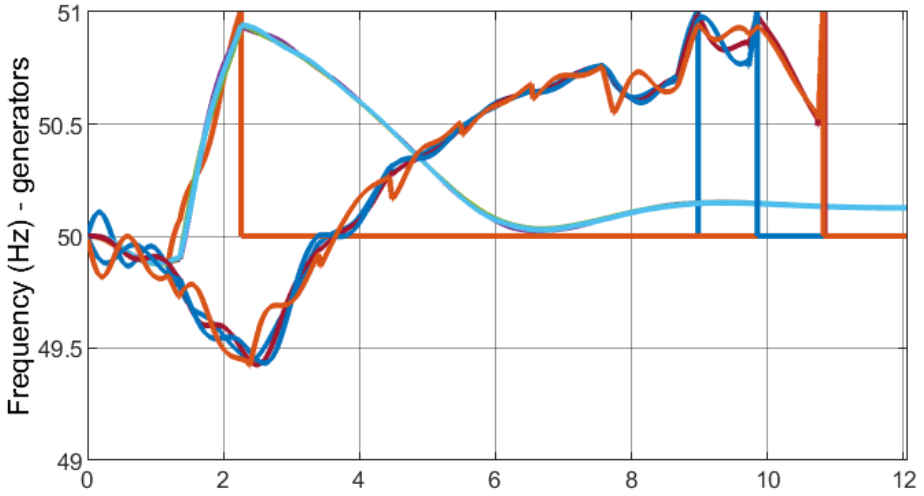
AC-CFM:
Total shedding = 58%

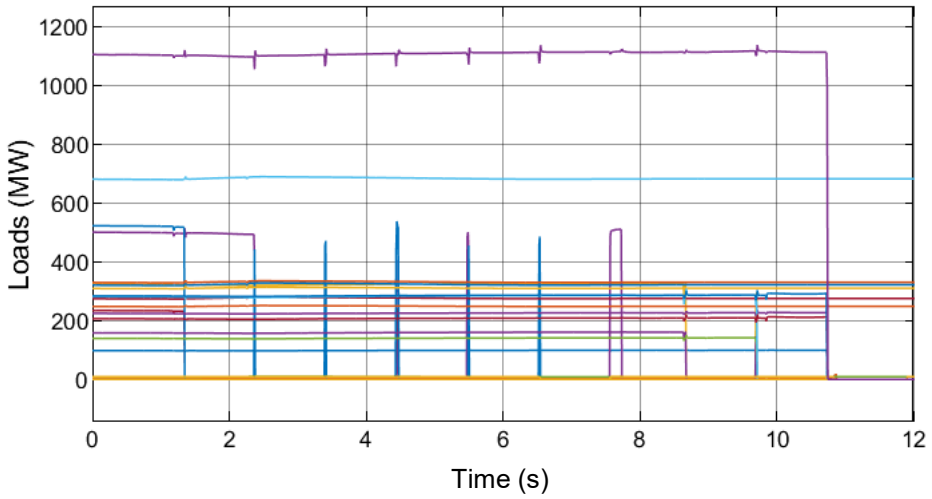


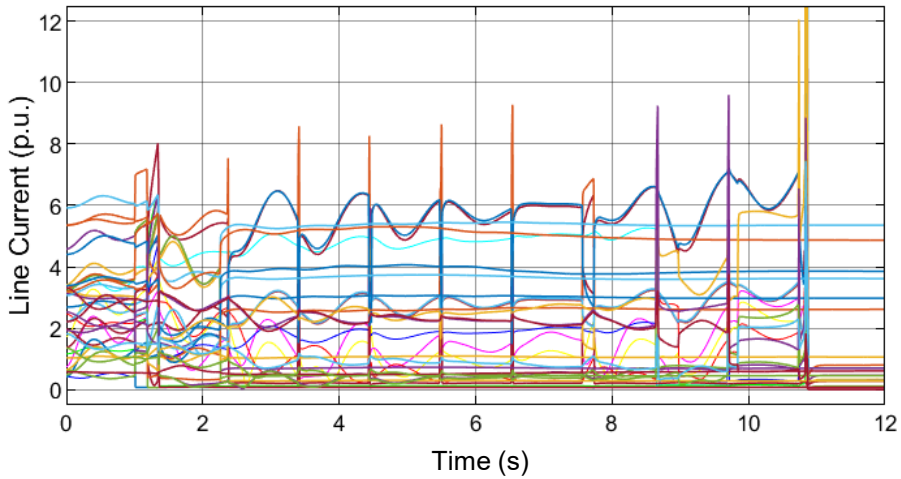
Results – Contingency 1 (line 4-14)

Progression of frequency (buses and generators), loads and line currents









Conclusions and Next Steps

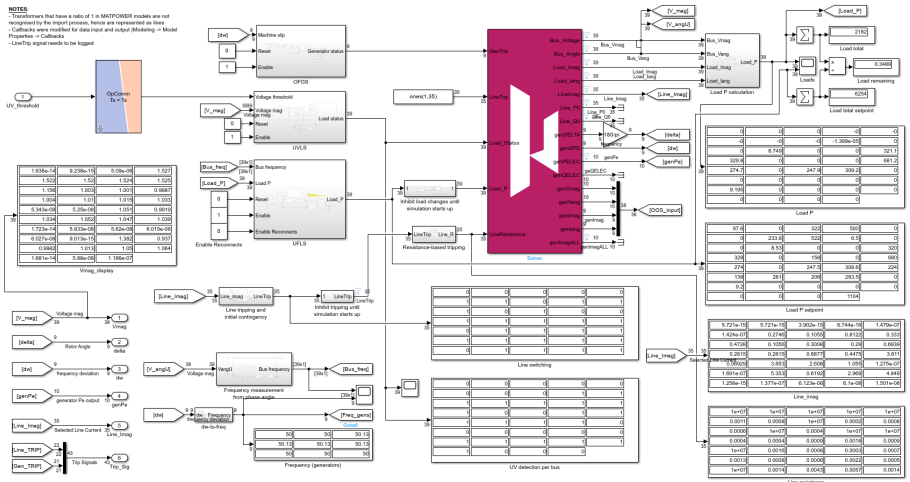
Validation through all event cycles, multiple networks

Open-source release

Multi-platform and multi-lab (e.g. OPAL-RT + Speedgoat)

Investigate effects of DSR, flexibility services, V2G etc.

Collaborations



Thank you for your attention! Questions?

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