Present and Future Operation of the Ireland Power System

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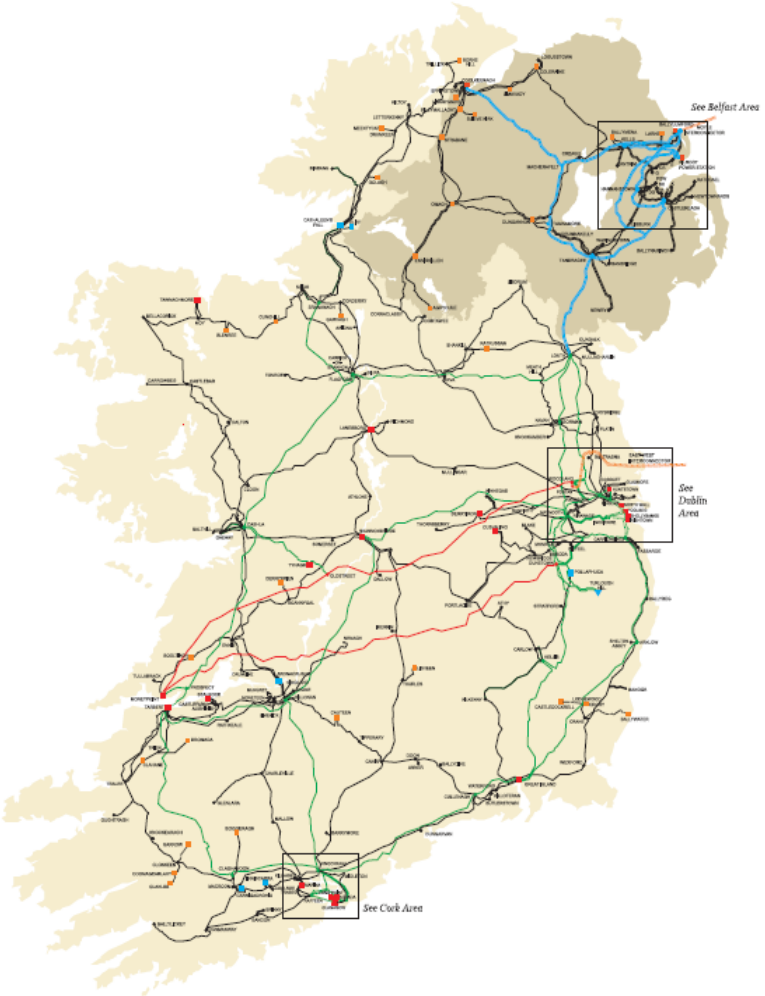
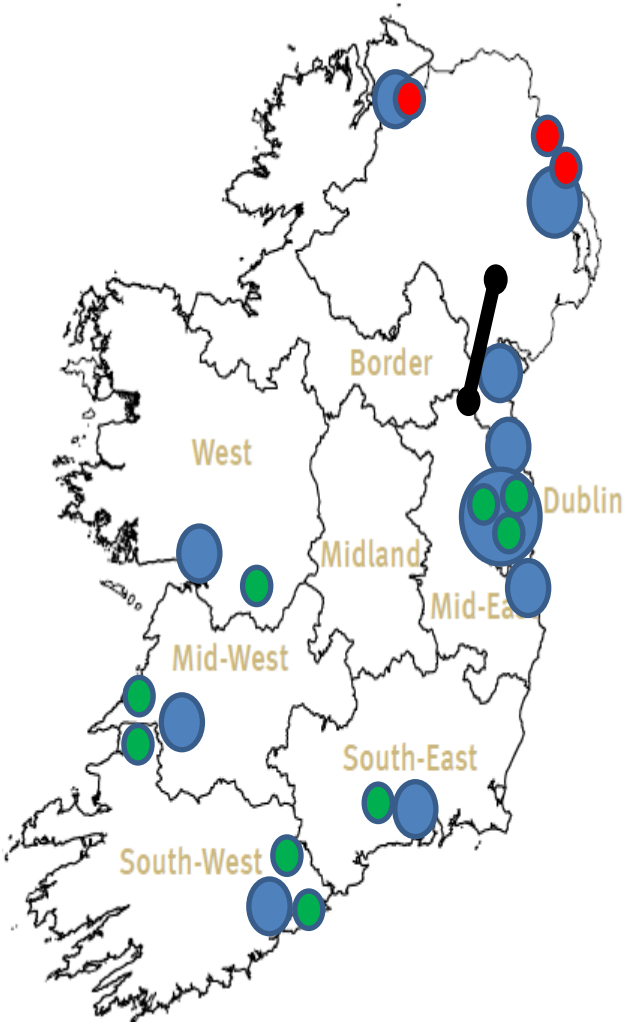
All-Island Power System



- Peak demand - 6.89 GW
- All-island, dual currency single electricity market (SEM)
- Gas / coal / peat / hydro / …
- 2 x 500 MW HVDC
- Wind capacity – (4.47) 5.58 GW
- Solar PV capacity – 336 MW
- Annual wind energy – 36%
- Maximum % wind – 147 / 96%
- SNSP stability limit – (71.8) 70%

Operational Rules All-Island



- Major load centres
- 3 units required in N. Ireland
- 5 units required in Ireland

Regional must-run plant

I-NI inter-area flow ≤ 400 MW

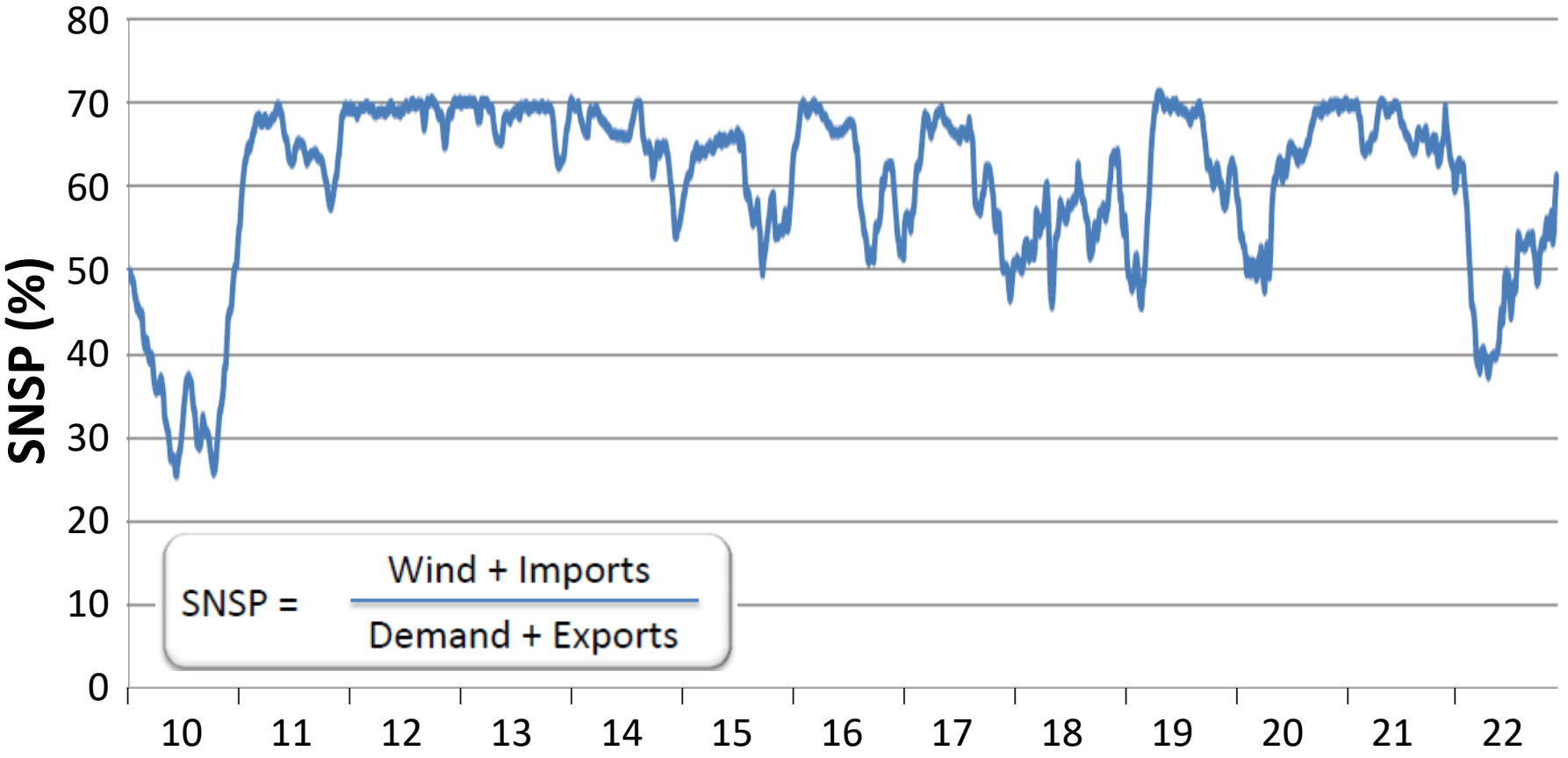
SNSP ≤ 70% (75%)

RoCoF ≤ 0.5 Hz/s (1.0 Hz/s)

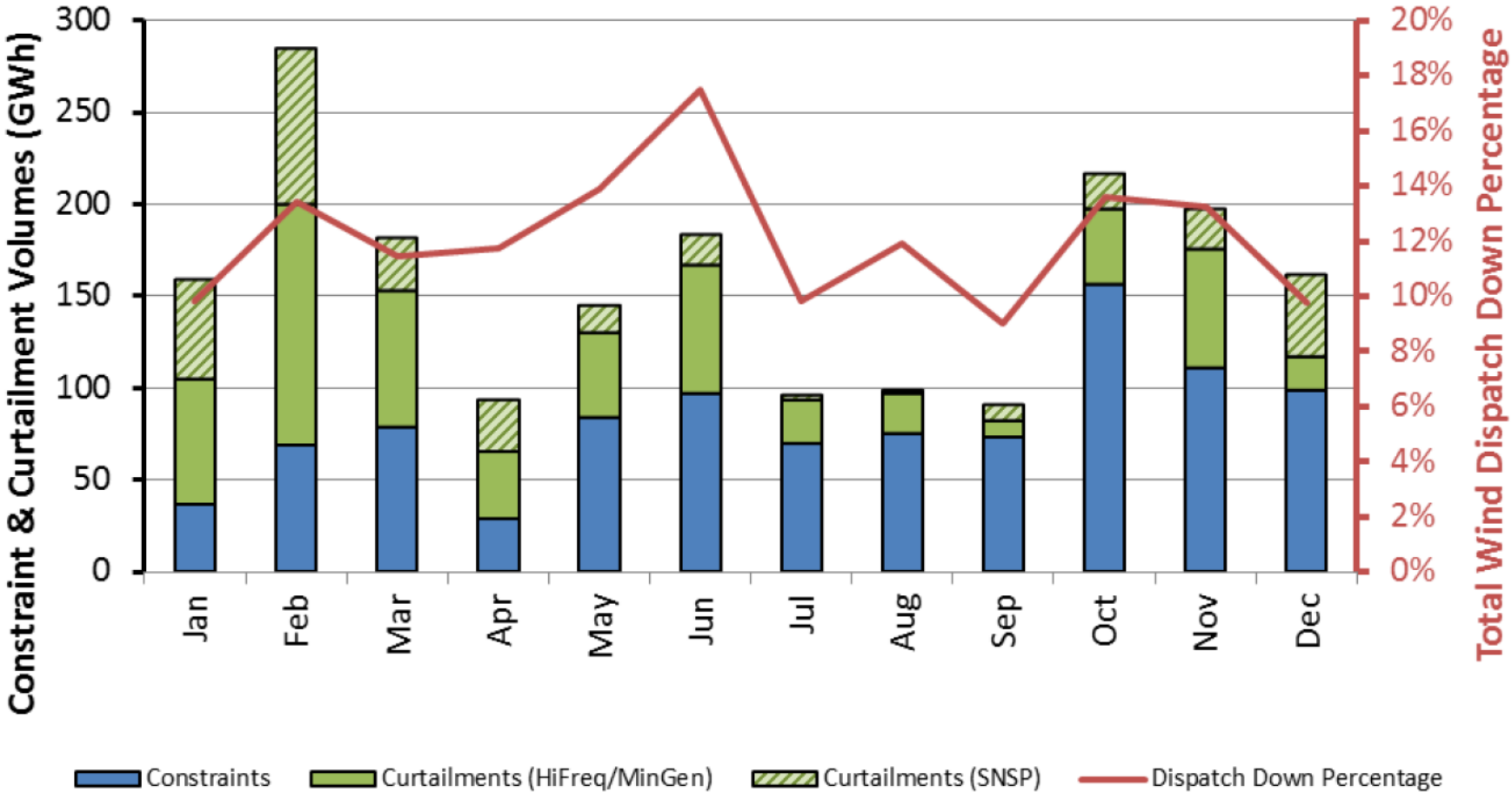
Inertia ≥ 23,000 MWs

System Non-Synchronous Penetration

February 2021

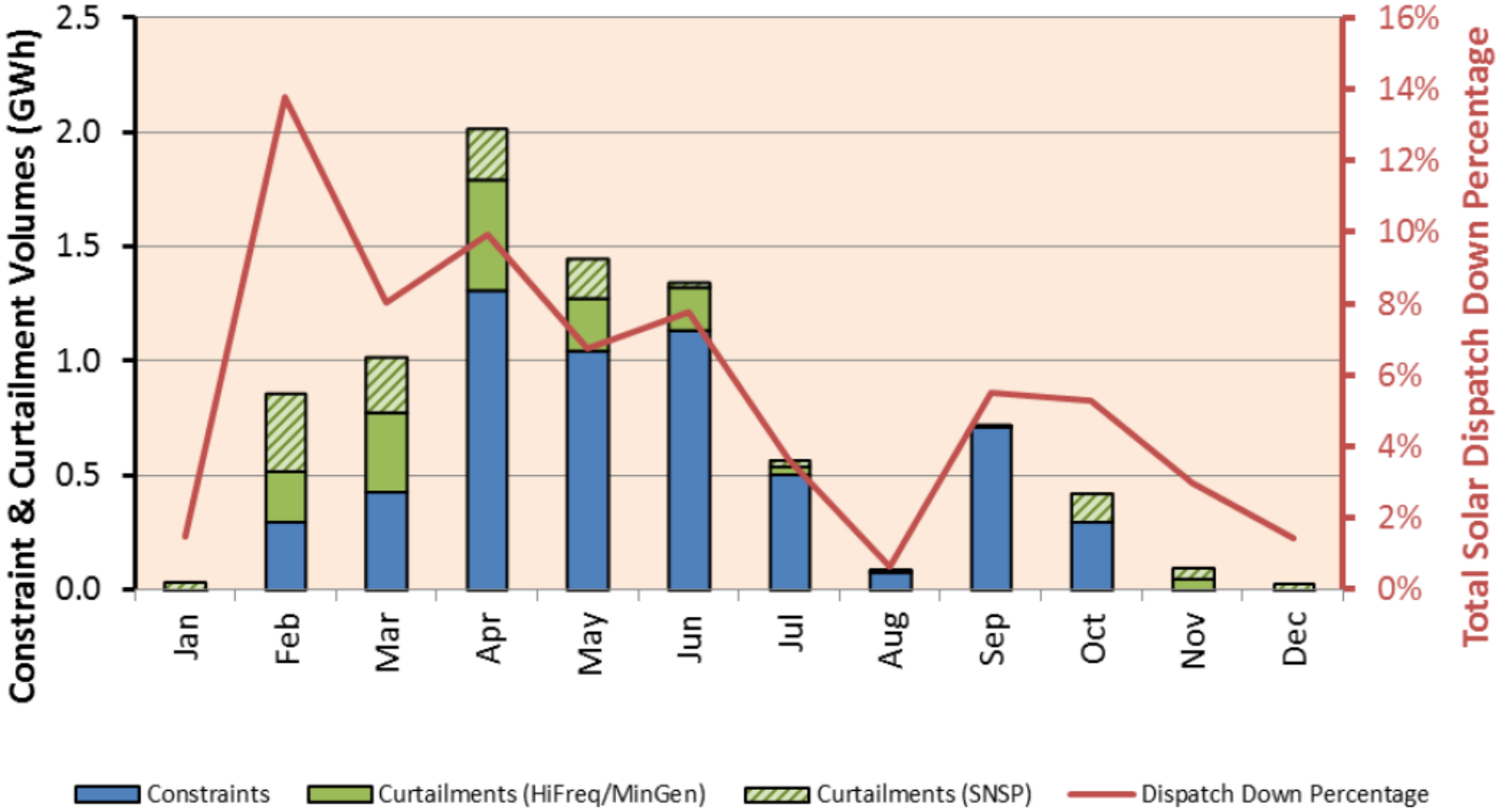


Wind Dispatch Down 2020



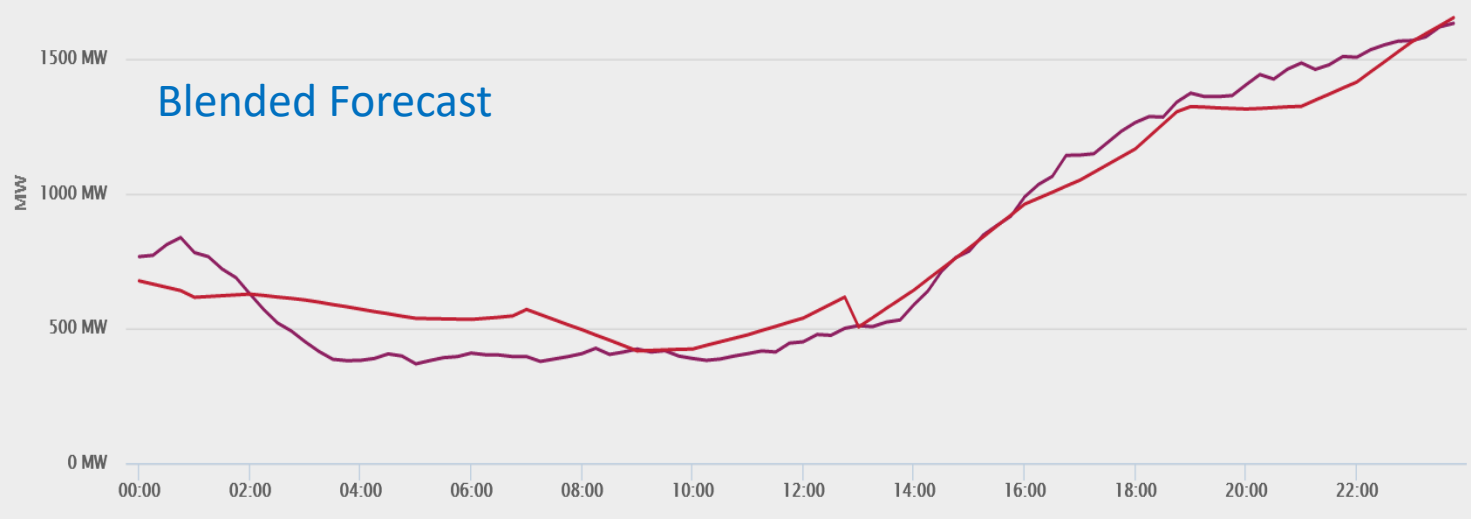
Solar PV Dispatch Down 2020

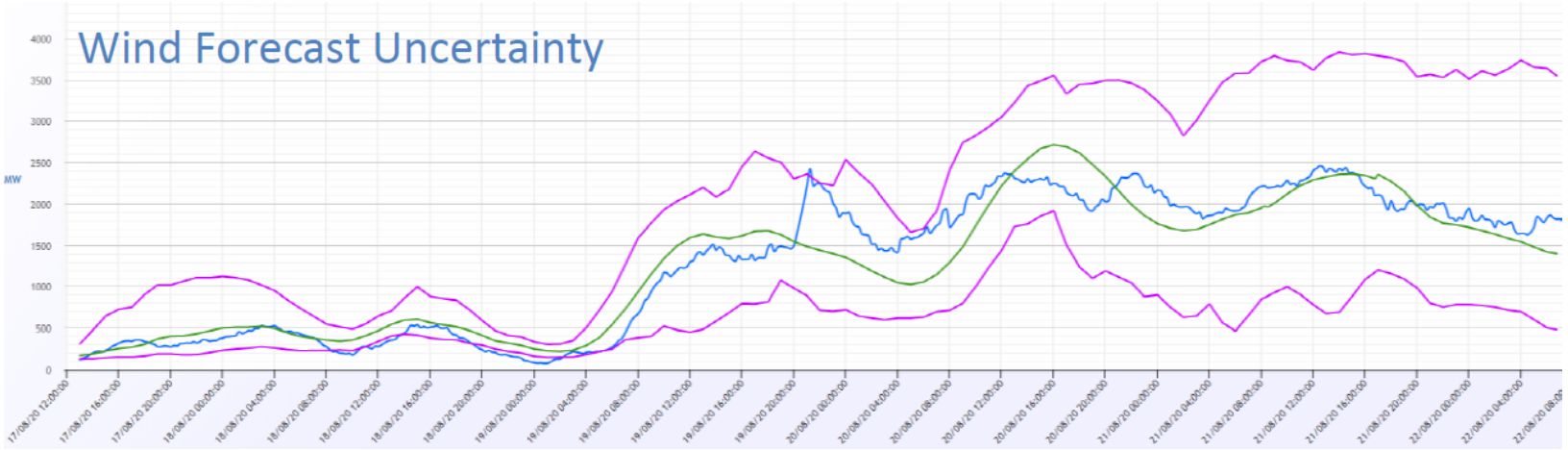
Northern Ireland



Wind Forecasting

- Primary and secondary wind vendors appointed





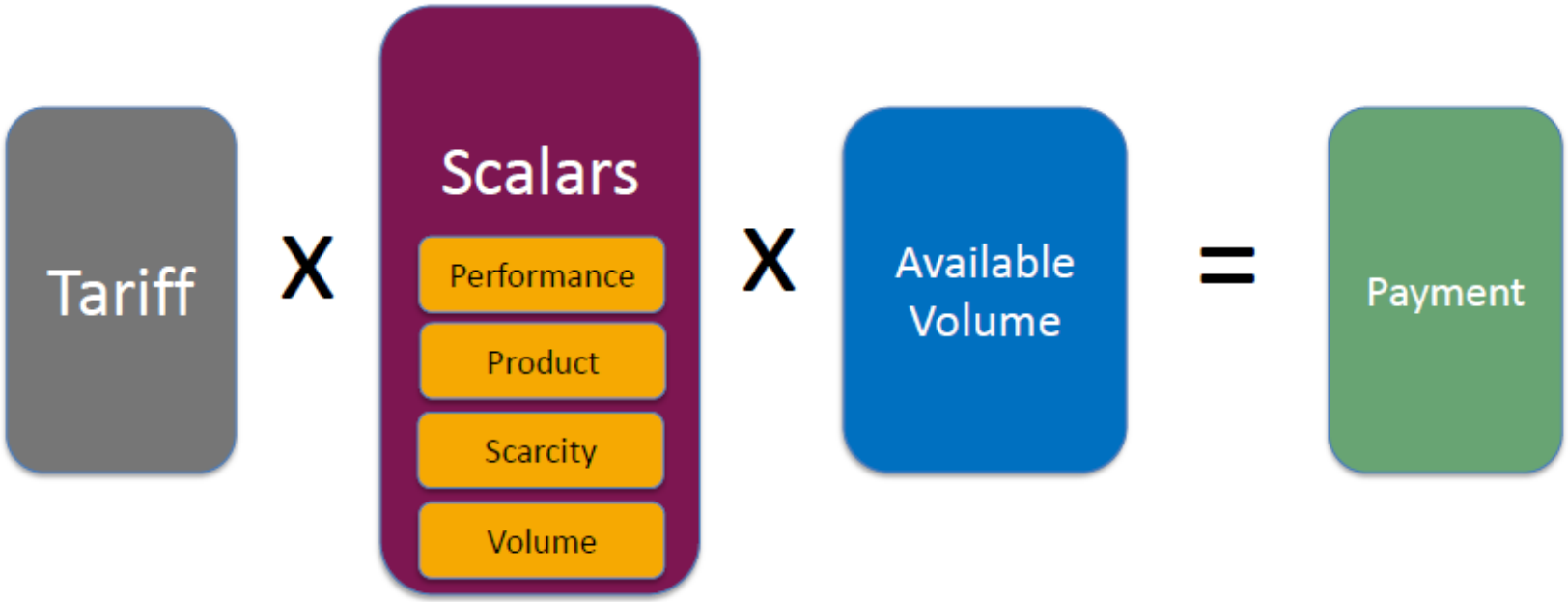
System Services Categories

Reserve	Primary Operating Reserve	Secondary Operating Reserve	Tertiary Operating Reserve 1
Ramping	Tertiary Operating Reserve 2	Replacement Reserve (De-synchronised + Synchronised)	
Reactive Power	Steady-State Reactive Power		

System Services Categories October 2018

Reserve	Primary Operating Reserve	Secondary Operating Reserve	Tertiary Operating Reserve 1	
Ramping	Tertiary Operating Reserve 2	Replacement Reserve (De-synchronised + Synchronised)		Ramp Margin (1 hr + 3 hr + 8 hr)
Reactive Power	Steady-State Reactive Power			
Inertia	Synchronous Inertial Response			
Fast-acting	Fast Frequency Response	Fast Post-Fault Active Power Recovery*		Dynamic Reactive Reserve*

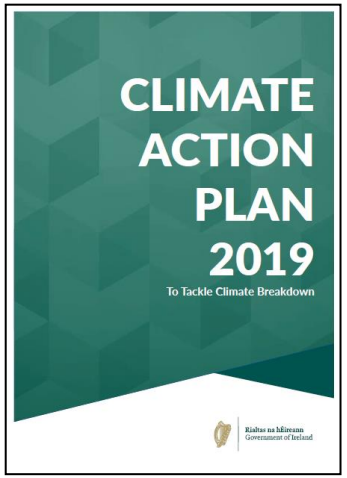
Payment Arrangements



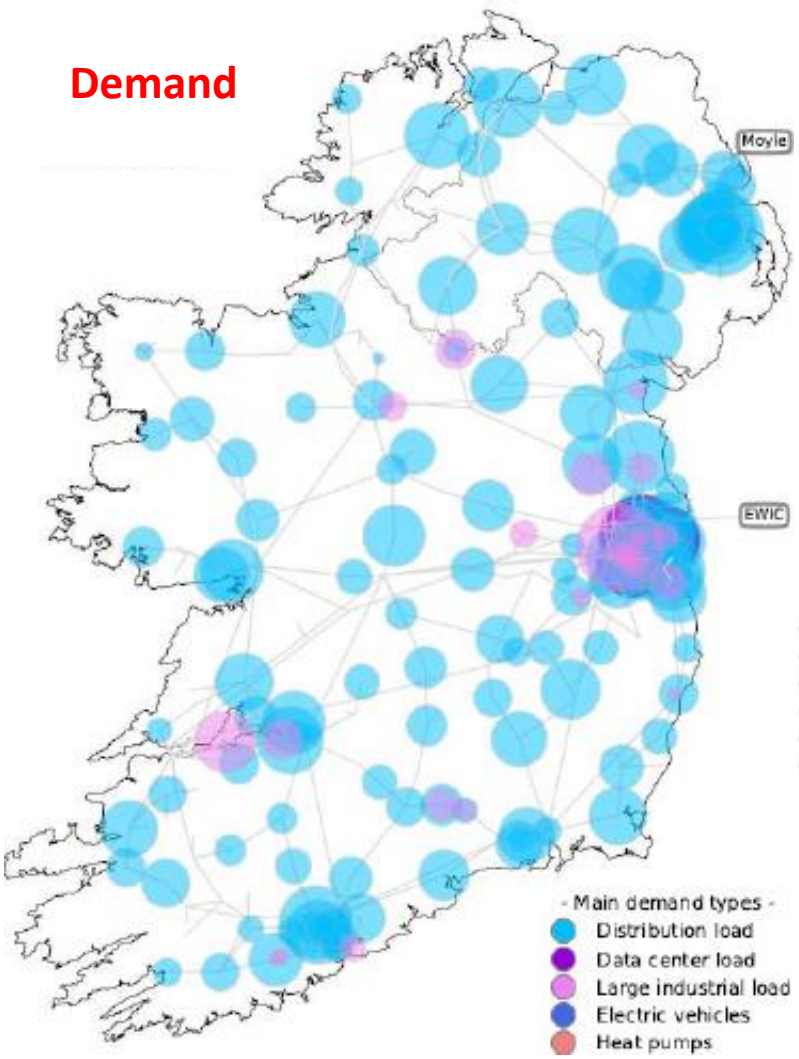
Performance scalar ~ Reliability of service
~ Speed of response
~ Dynamic response (non-stepped)
~ Enhanced delivery (multiple products)
~ Scarcity of supply (temporal and locational)
~ Availability forecast accuracy ?

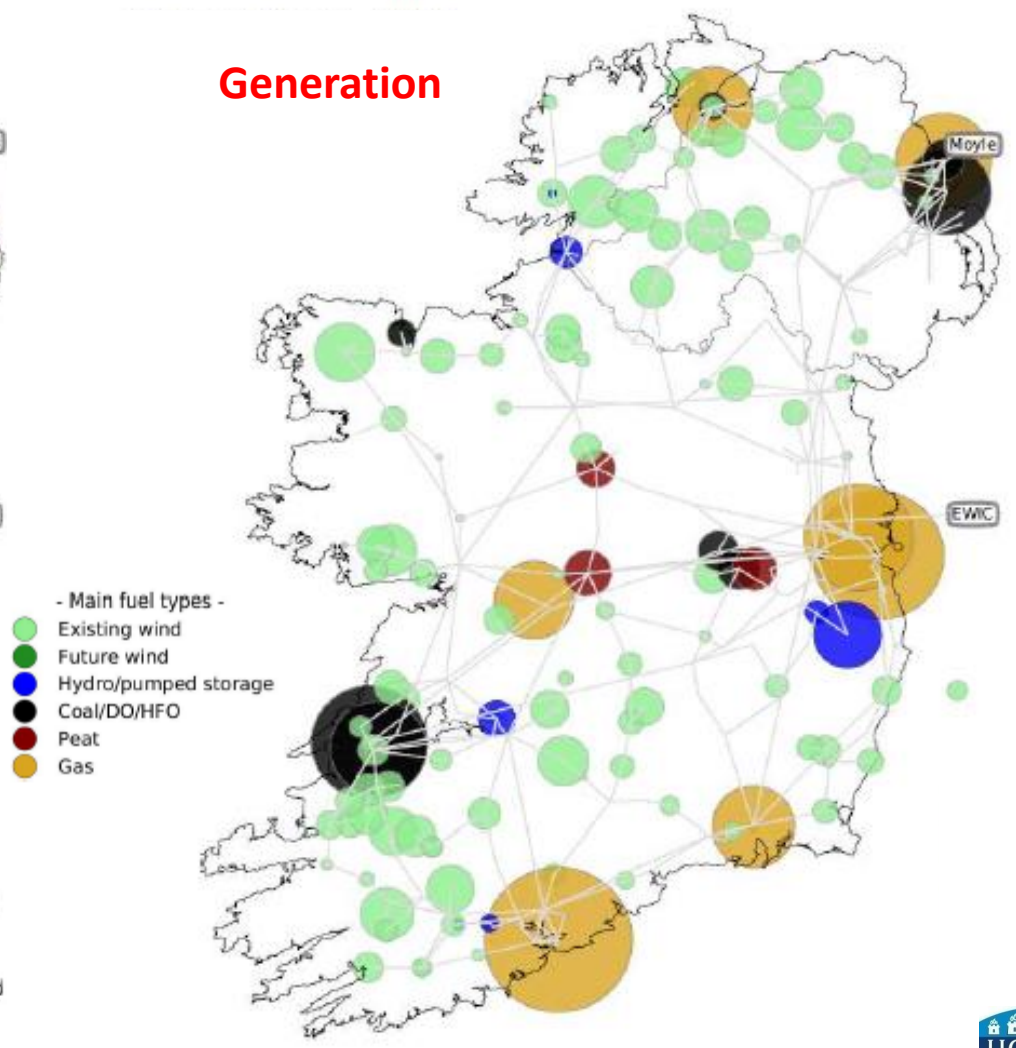
Climate Action Plan 2019

- 70% renewables target by 2030
- < 8.2 GW onshore & 3.5+ GW offshore wind capacity
- < 1.5 GW grid-scale solar capacity
- 70 GW ocean energy potential
- Carbon tax of €80+ by 2030
- Develop district heating roadmap
- 950,000 EVs on the road
- 600,000 heat pumps at residential level
- *Support for net zero emissions target by 2050*
- Climate Bill – 51% emissions reduction by 2030

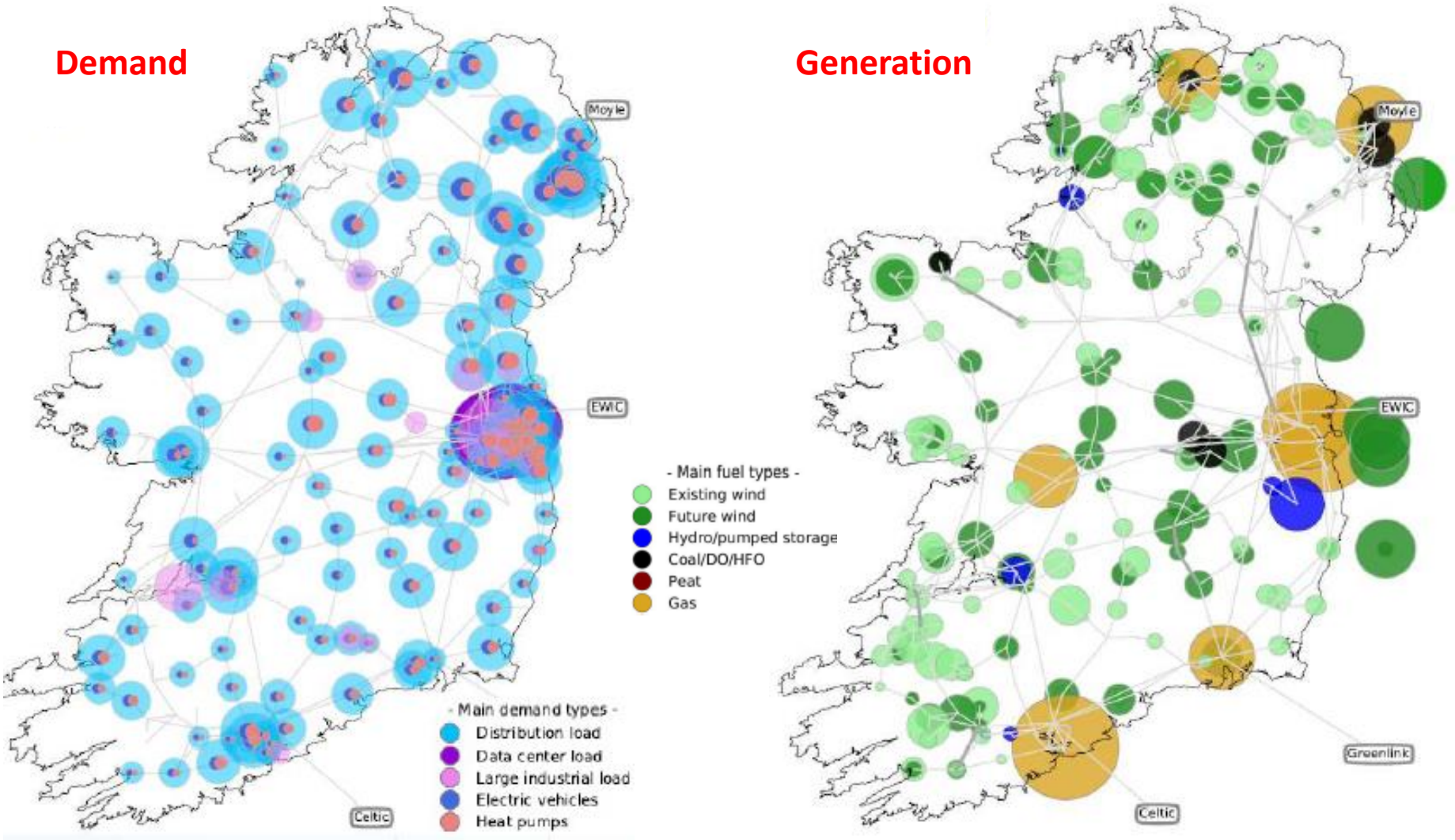


Demand vs. Generation 2020

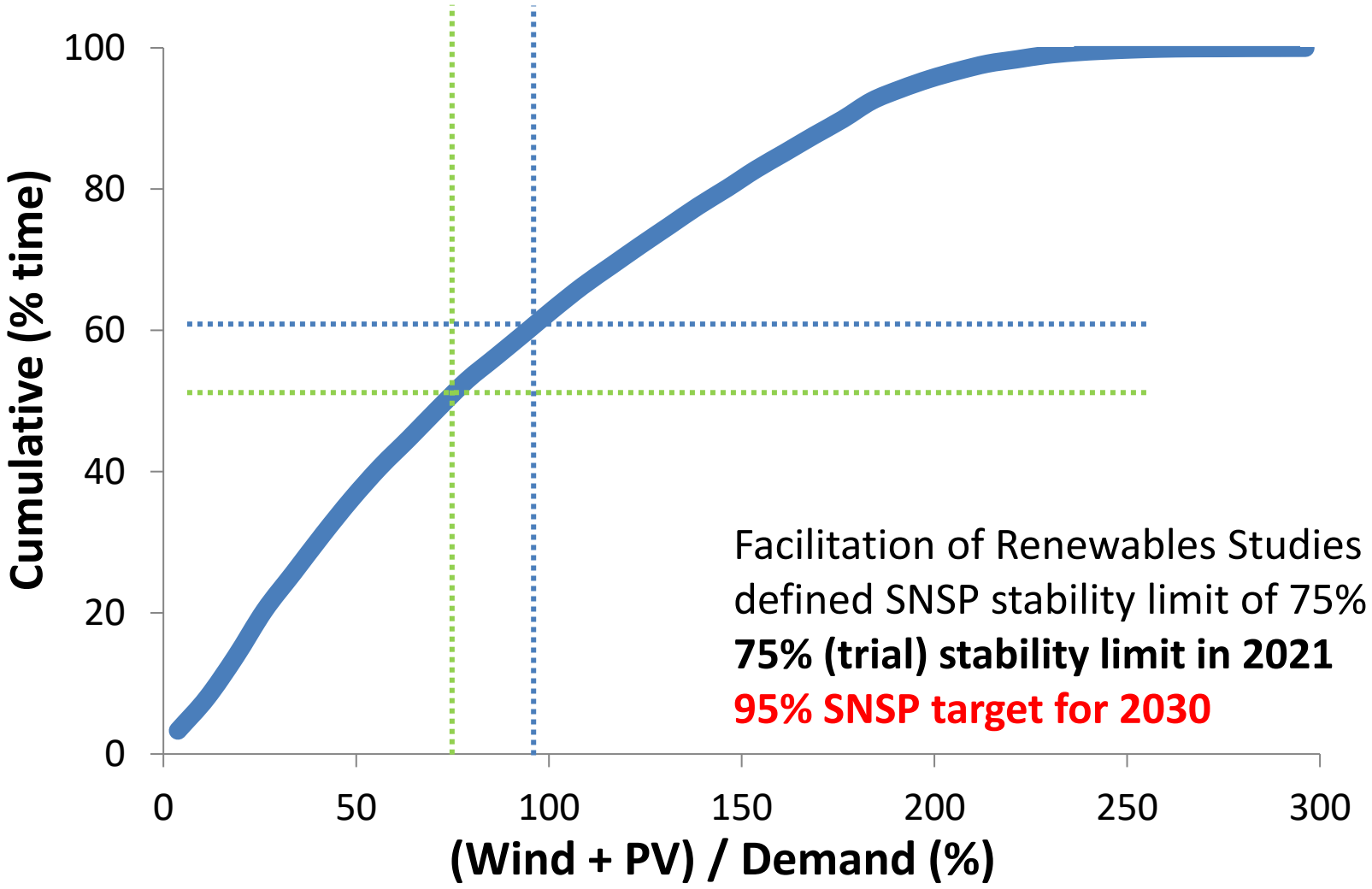




Demand vs. Generation 2030



Ireland + N. Ireland 2030



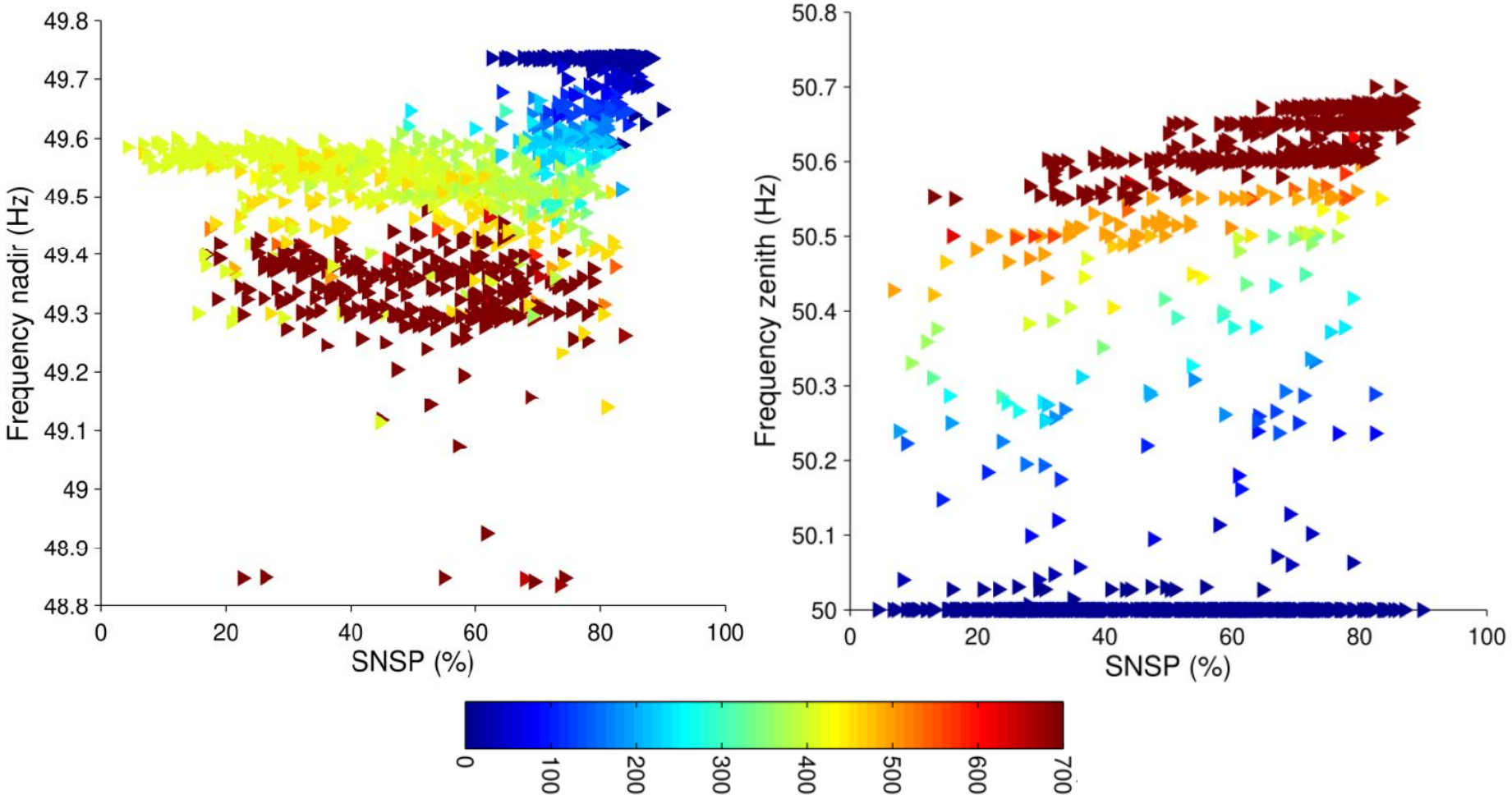
SNSP – System non-synchronous penetration

System Scarcities 2030

No Scarcity	Evolving Characteristic	Concern	Scarcity

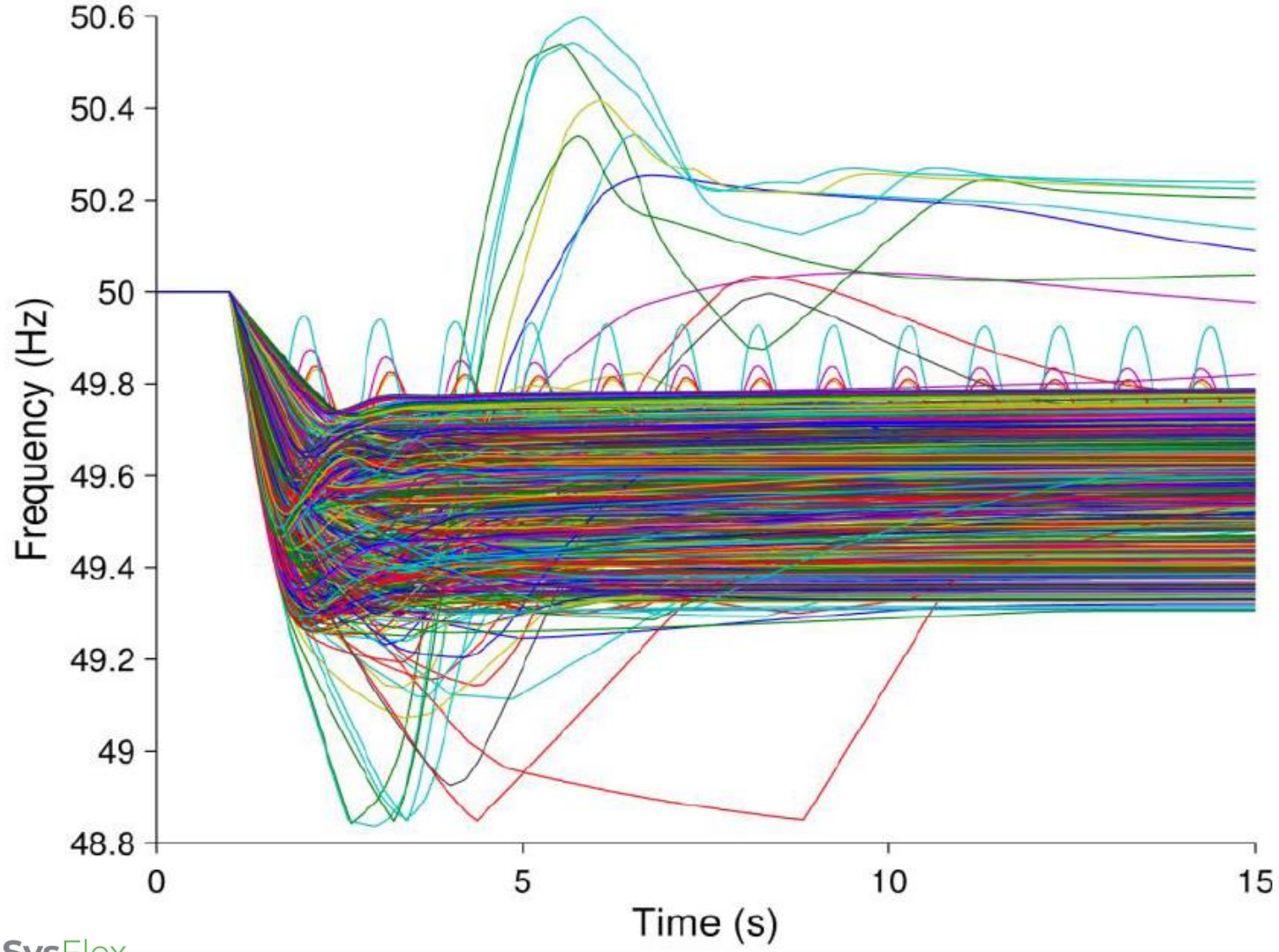
	Continental Europe	Ireland & Northern Ireland	Nordic System
RoCoF (dimensioning incident)	Localised concern	Inertia scarcity	Evolving characteristic
RoCoF (system split)	Global concern	N/A	Not analysed
Frequency containment (dimensioning incident)	Evolving characteristic	Evolving characteristic	Evolving characteristic
Frequency containment (system split)	Global concern	N/A	Not analysed
Steady State Voltage Regulation	SS reactive power scarcity	SS reactive power scarcity	
Fault Level	No scarcity	Dynamic reactive injection scarcity	
Dynamic Voltage Regulation	No scarcity	Dynamic reactive injection scarcity	
Critical Clearing Times	Evolving characteristic	Evolving characteristic	
Rotor Angle Margin	Not analysed	Localised concern	
Oscillation Damping	Damping scarcity	Damping scarcity	
System Congestion	Global concern	Transmission capacity scarcity	
System Restoration	Not analysed	Evolving characteristic	

Loss of Largest Infeed/Outfeed



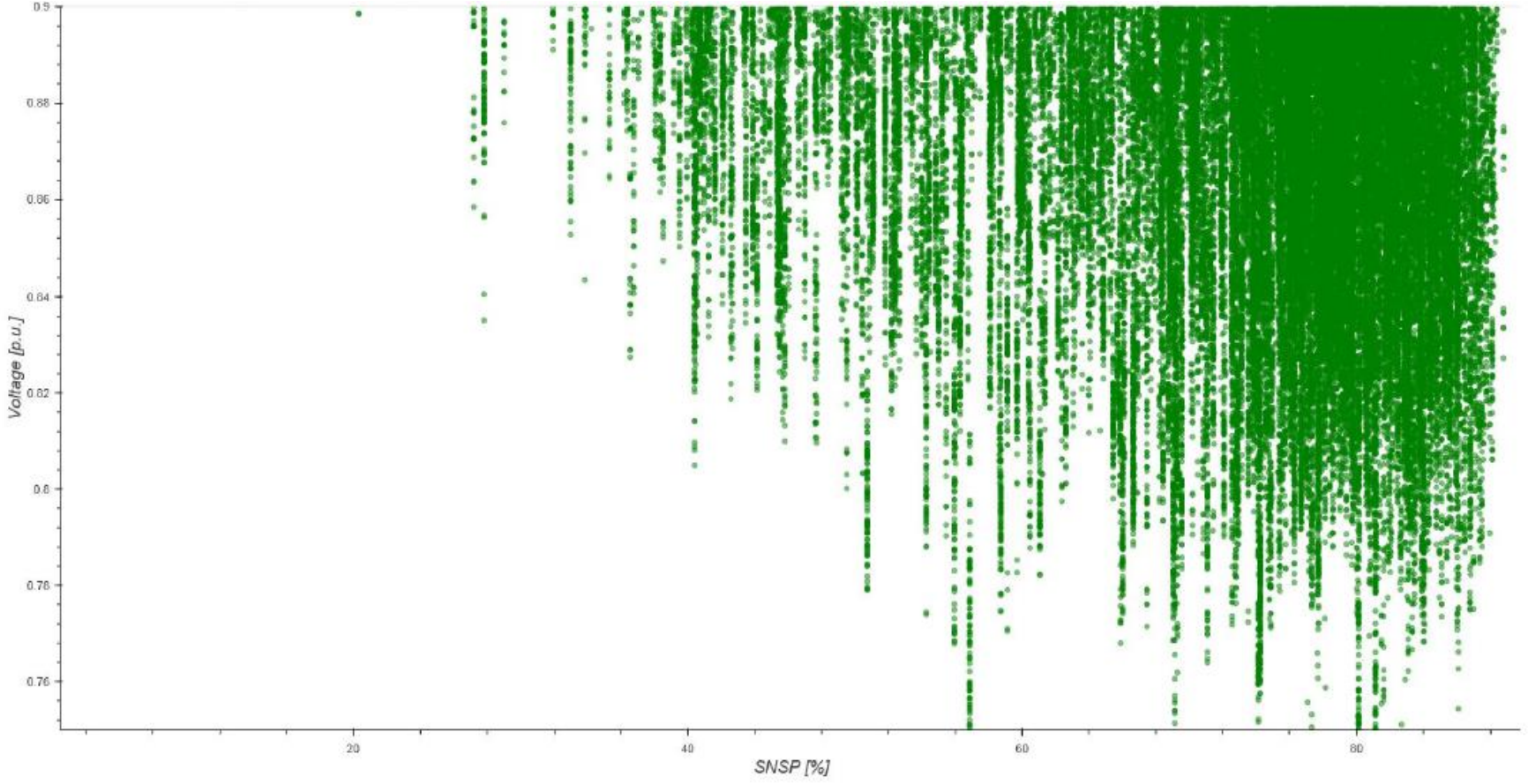
Technical shortfalls for pan-European power system with high levels of renewable generation, EU SysFlex project

Loss of Largest Infeed



N-1 Low Voltage Scenarios

Shortage of steady-state reactive power capability

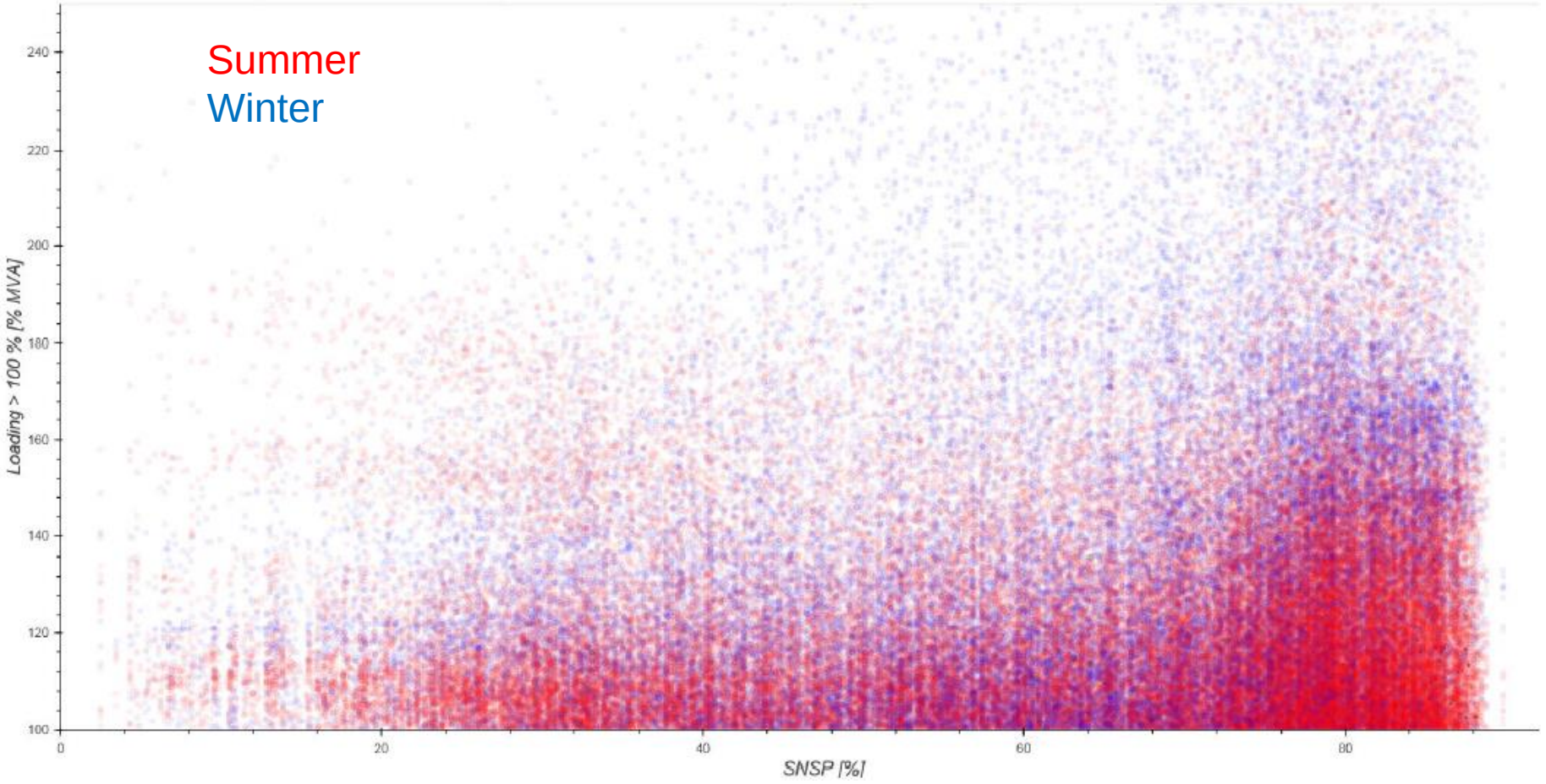


EU-SysFlex

UCD DUBLIN

N-1 Transmission Network Overloading

Desirability for congestion related system service?



EU-SysFlex

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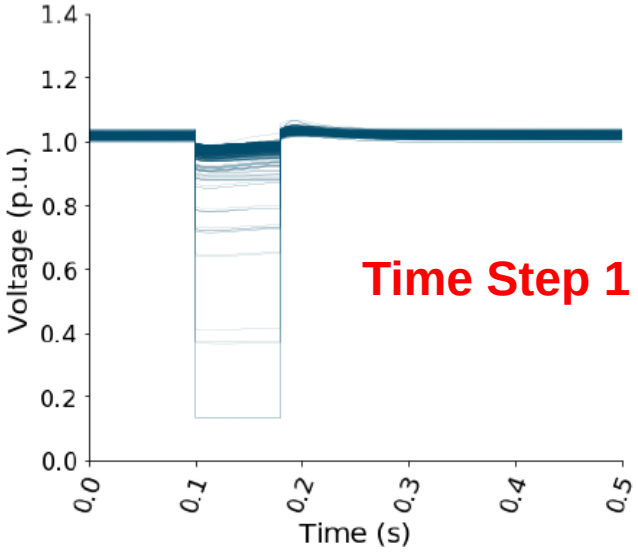
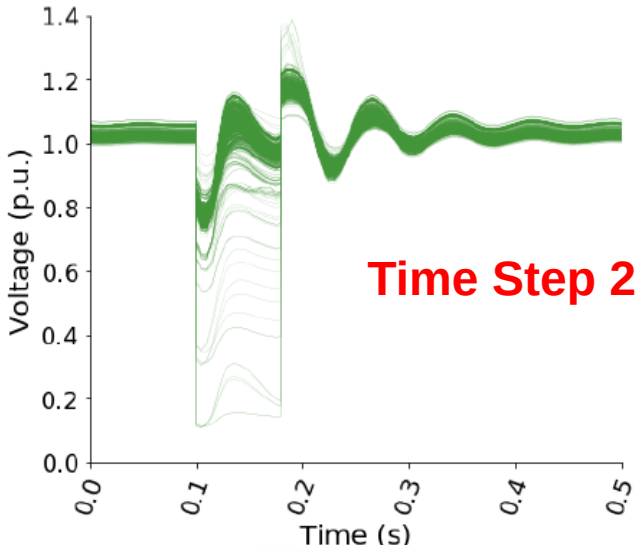
Bolted 3-Phase Line Faults

Requirement for dynamic reactive response capability

Fault Location A

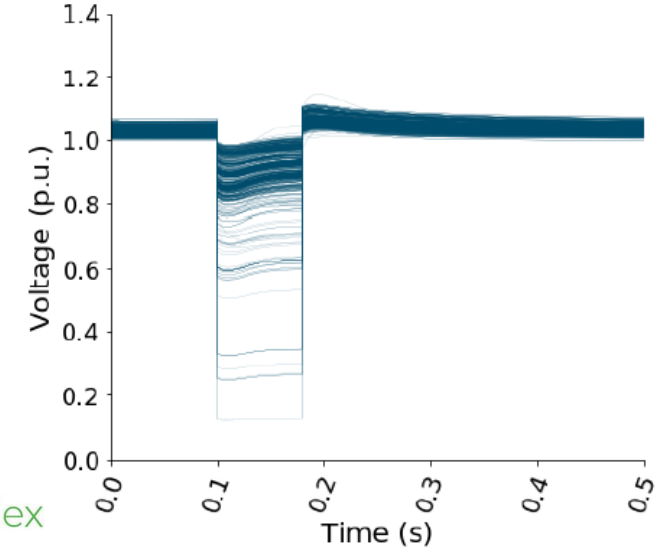


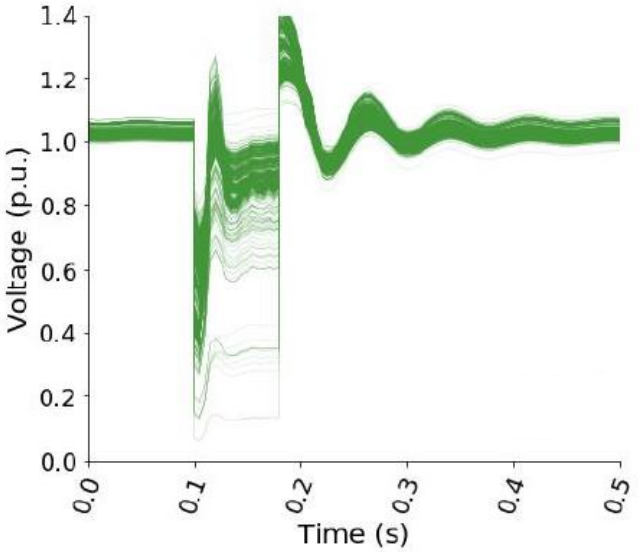
Time Step 1



Time Step 2

Fault Location B





EU-SysFlex

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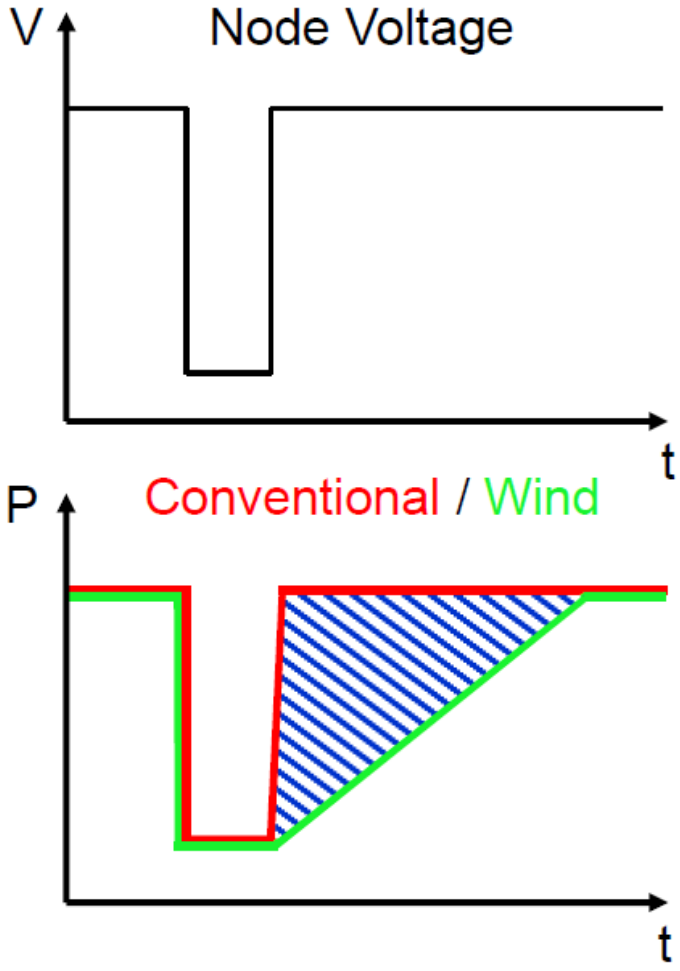
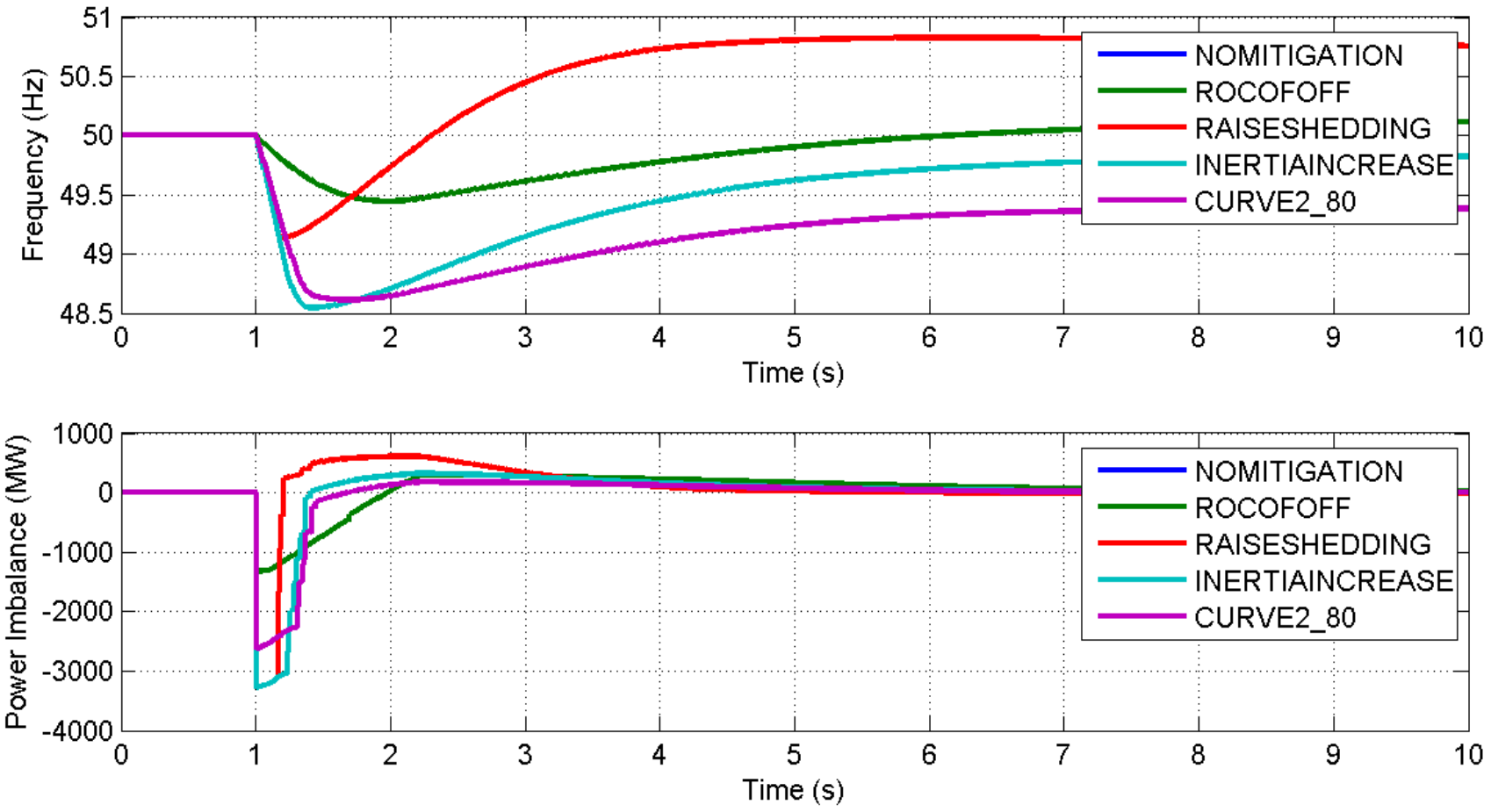
Voltage Dip-Induced Frequency Dips



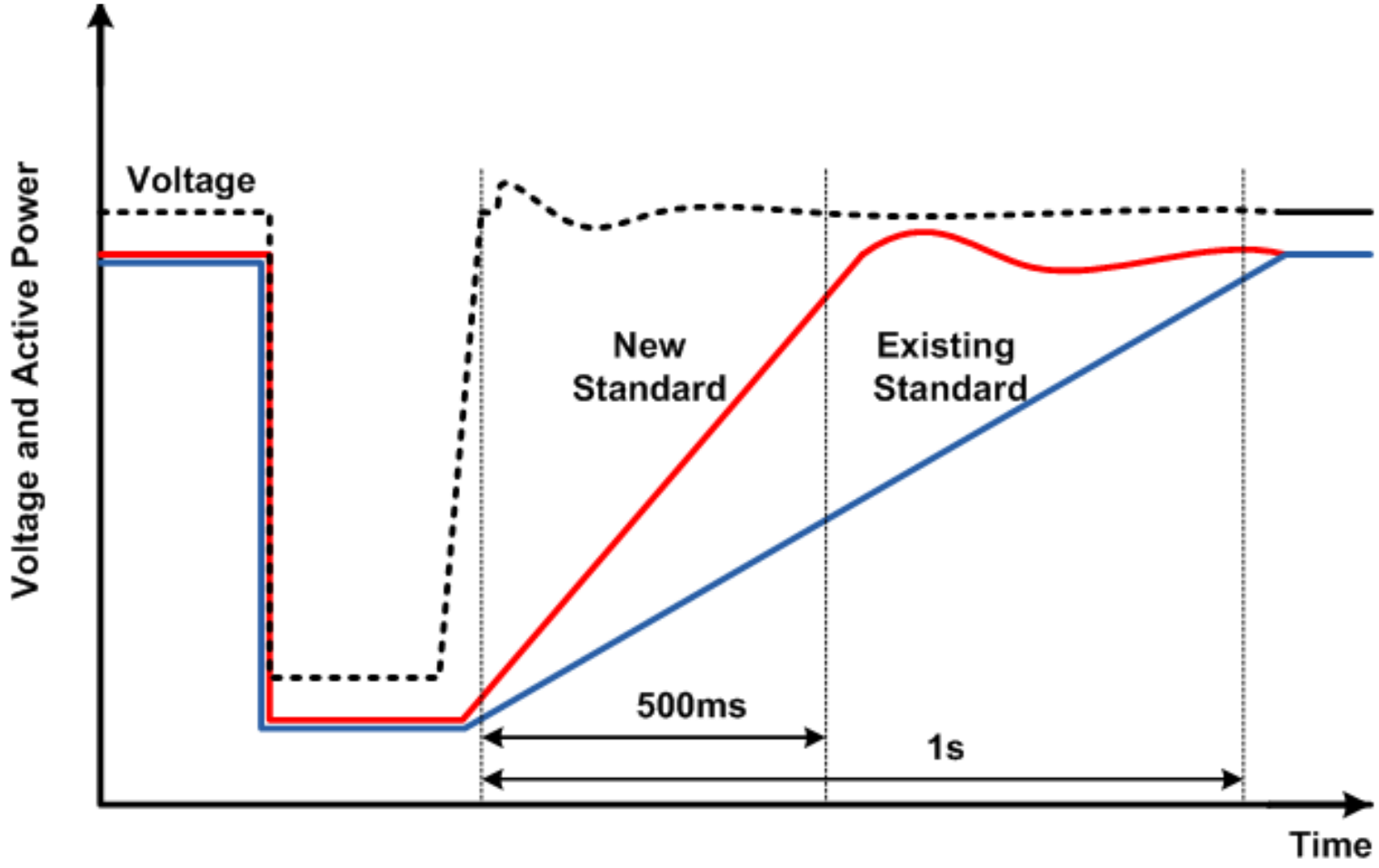
Voltage Profile

- Red < 15%
- Yellow 15 – 50%
- Green 50 – 80%

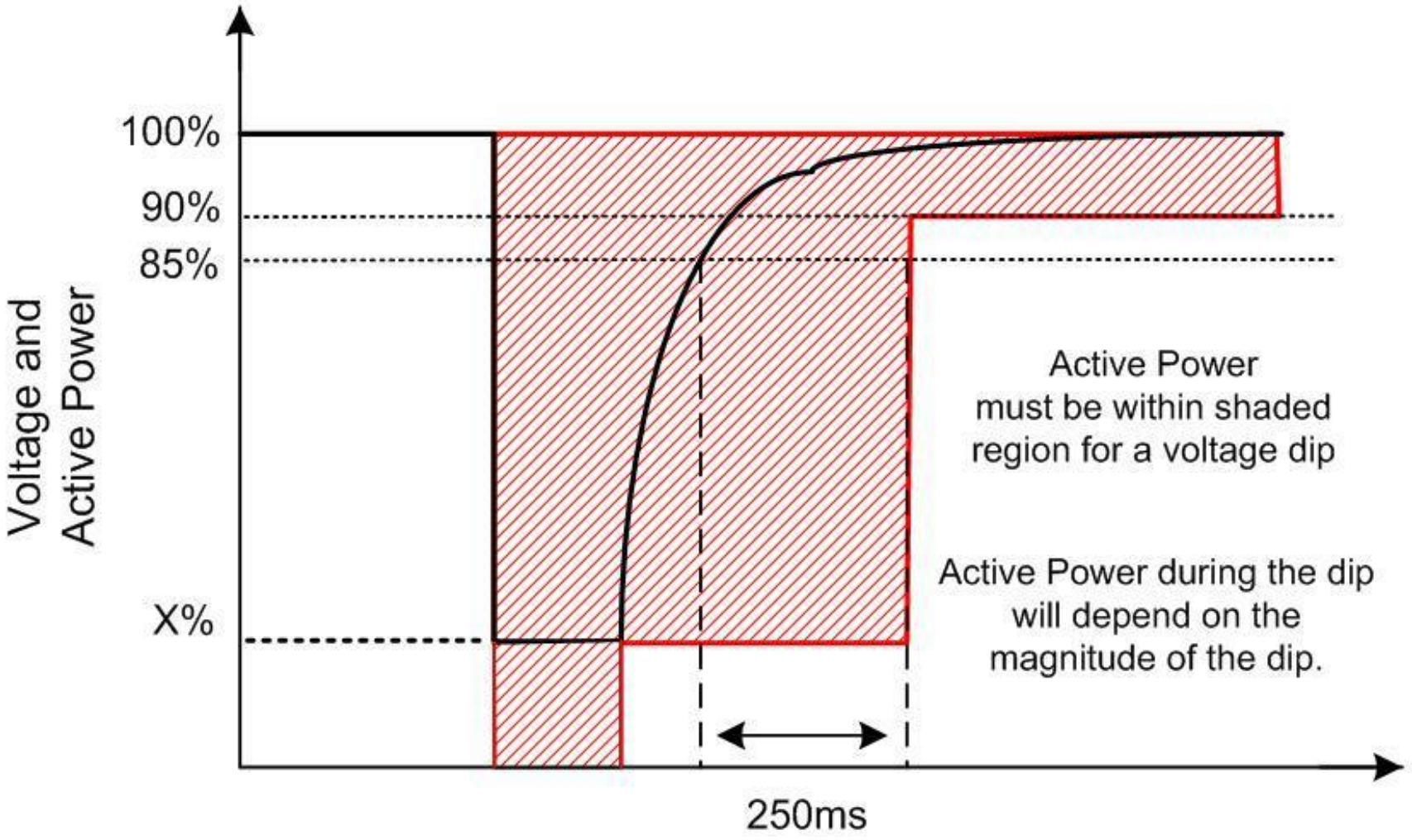
Voltage Dip-Induced Frequency Dips



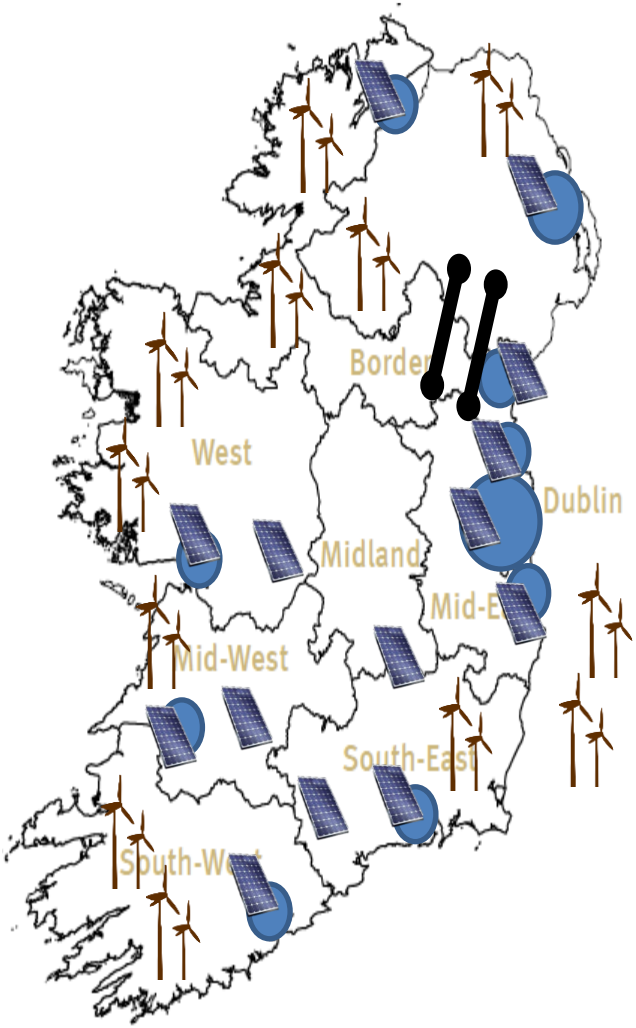
Post-Fault Active Power Recovery



Post-Fault Active Power Recovery



100% SNSP Scenario



- Major load centres
- PV generation
- Wind generation

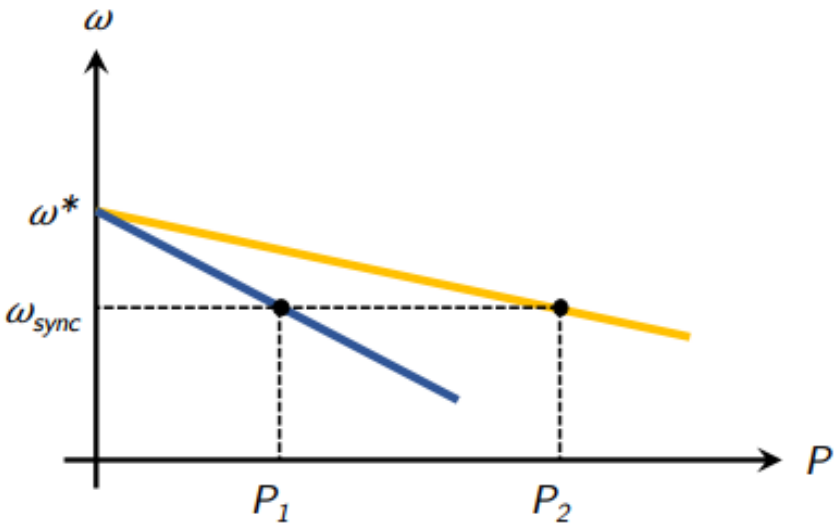
System grid-forming ratio

$$SGFR_{100} = \frac{GF_{online}}{GF_{online} + gf_{online}}$$

System non-synchronous penetration

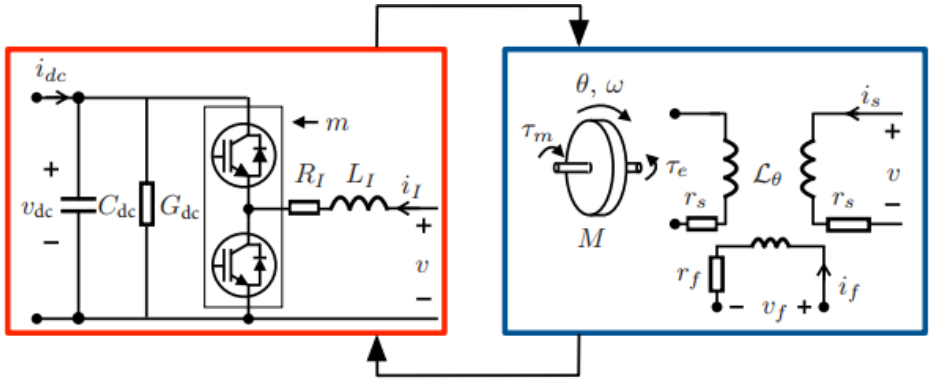
$$SNSP = \frac{P_W + P_{HVDC(imp)}}{P_L + P_{HVDC(exp)}}$$

Grid-Forming Control Strategies

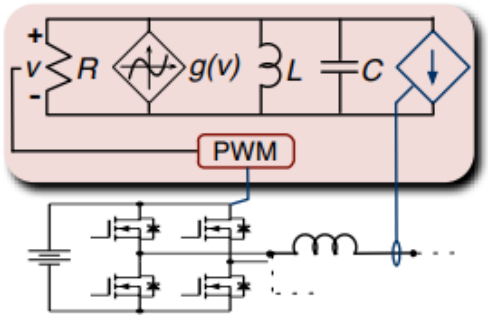


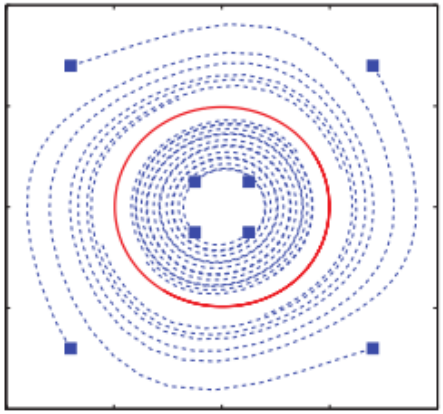
Droop control

$$\omega = \omega_{ref} + k(P - P_{ref})$$



Synchronous machine matching

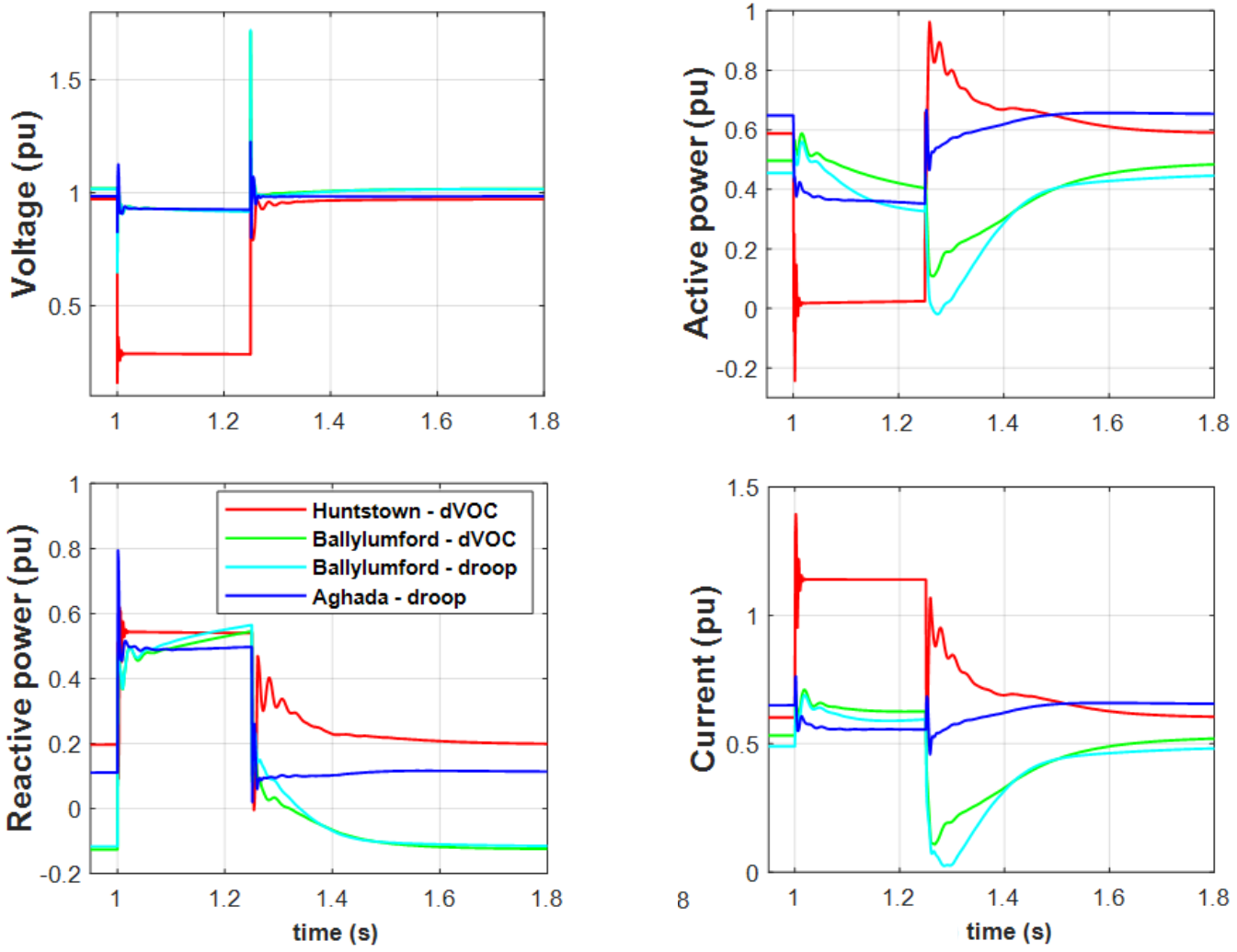




Virtual oscillator control (VOC)

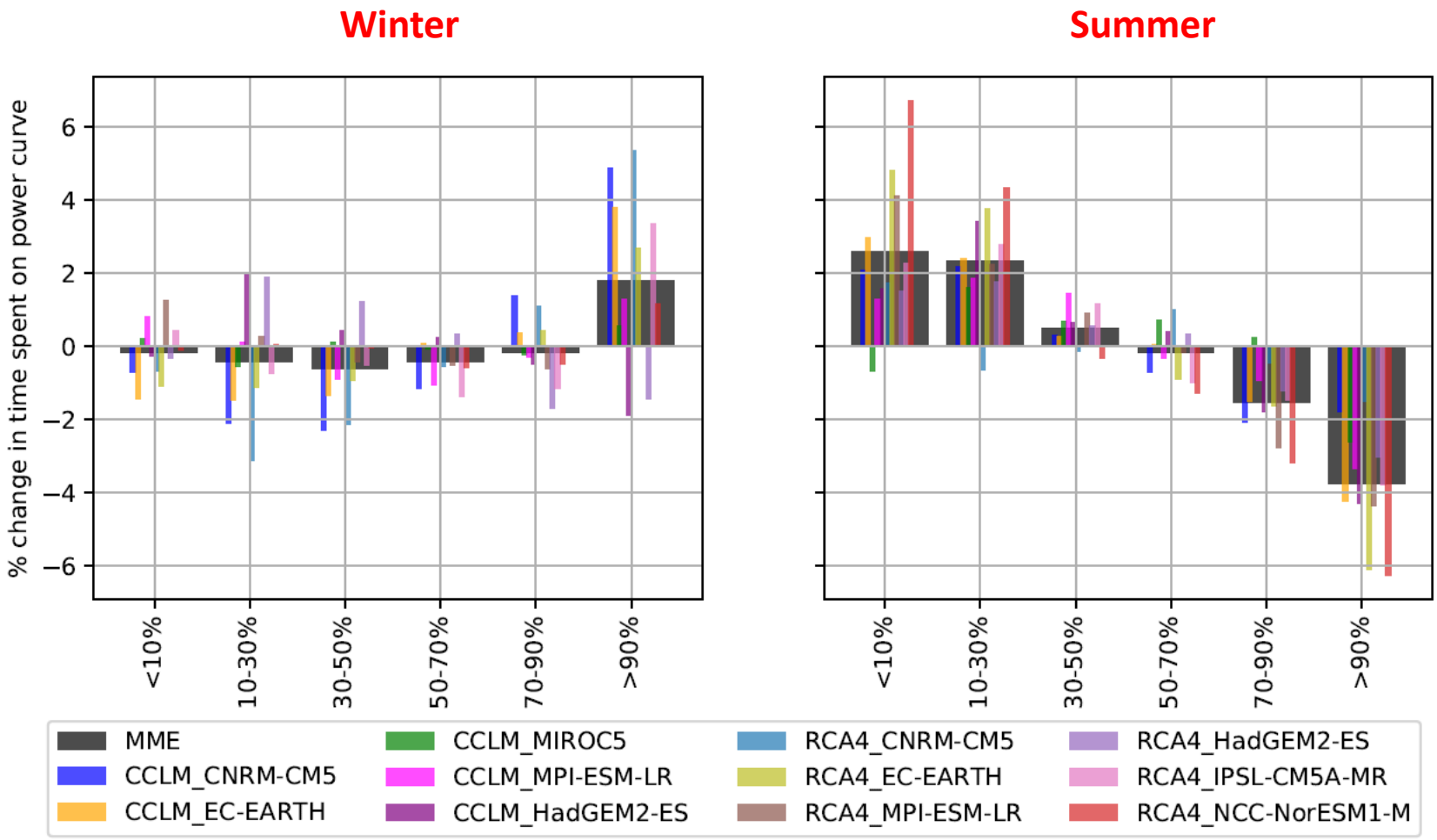
3-Phase Fault at Inchicore (near Dublin)

Mix of droop + dVOC grid-forming controls

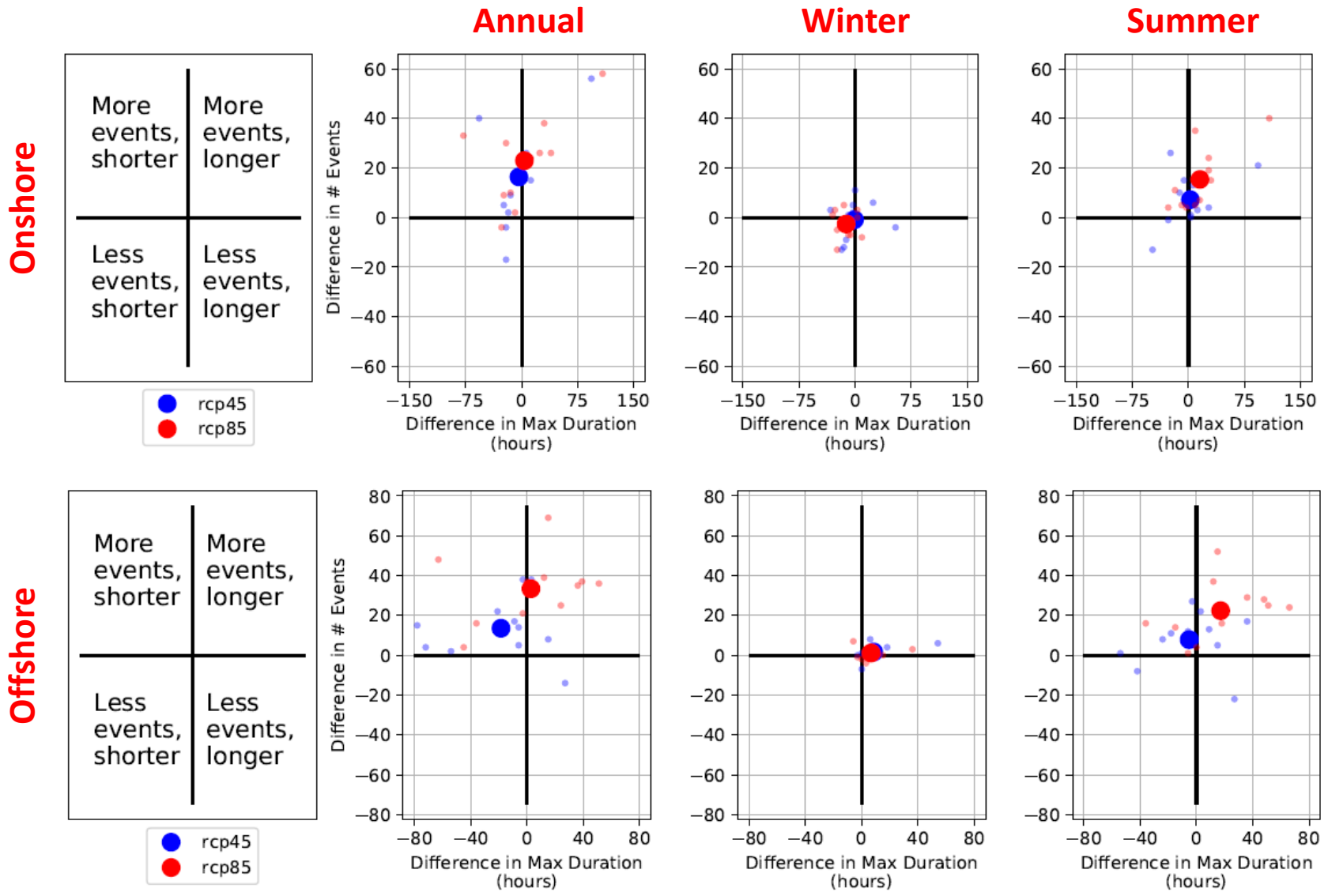


X. Zhao, D. Flynn: Stability assessment for 100% converter-based Irish power system, IET RPG

Wind Power Distribution 2081-2100



Extended Low-Power Events 2081-2100



… Some Open Questions

- How best to achieve cost effective operation while maintaining system stability with increasing RES?
- Can we avoid building new lines while facilitating demand growth and new generation?
- Growth and nature of *self-consumption*?
- How to incentivise plant portfolios which maintain system adequacy?
- Need for and desirability of seasonal storage?
- *Should CO_2 reduction objectives outweigh economic / least cost motivations?*

Present and Future Operation of the Ireland Power System

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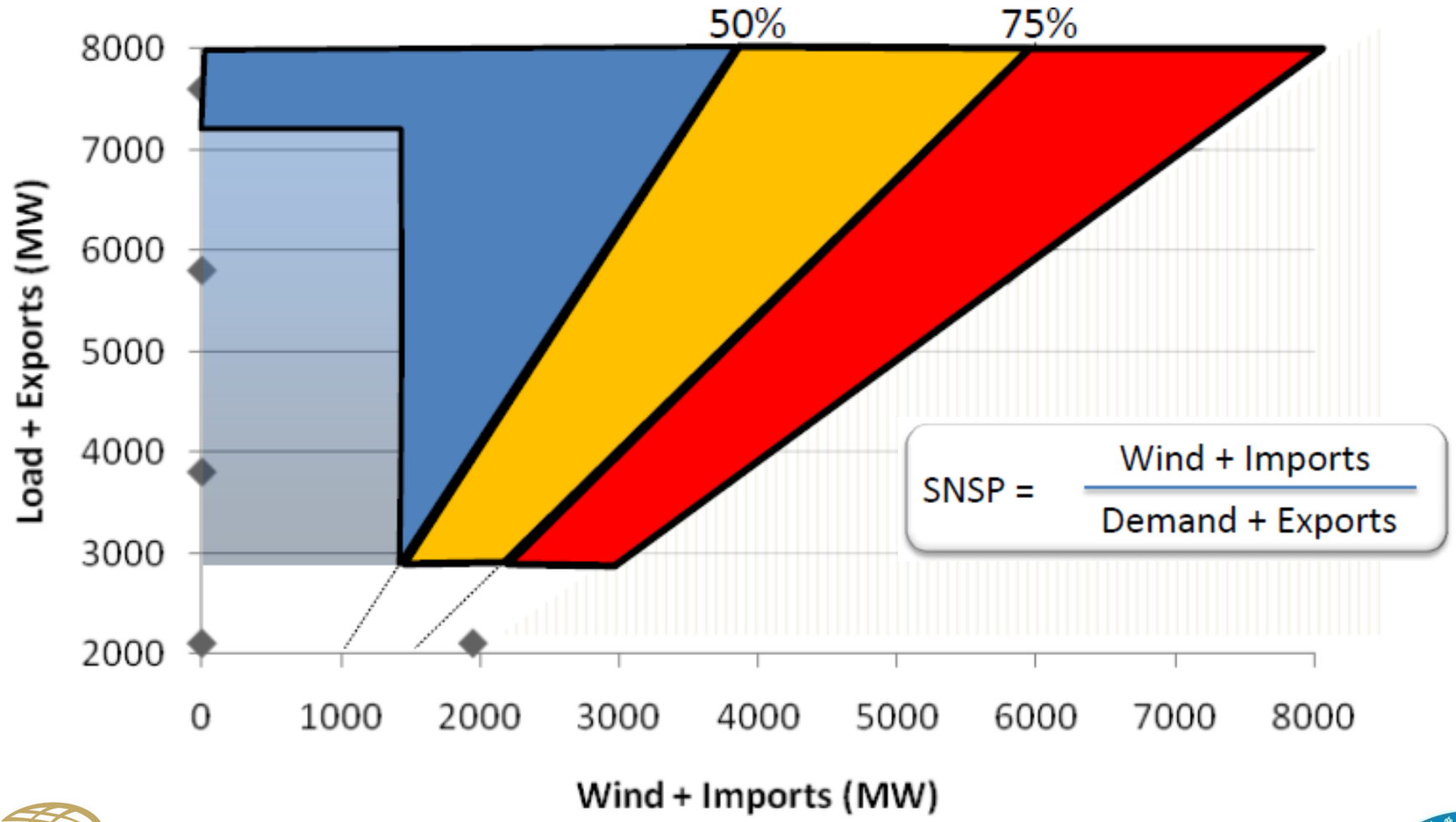
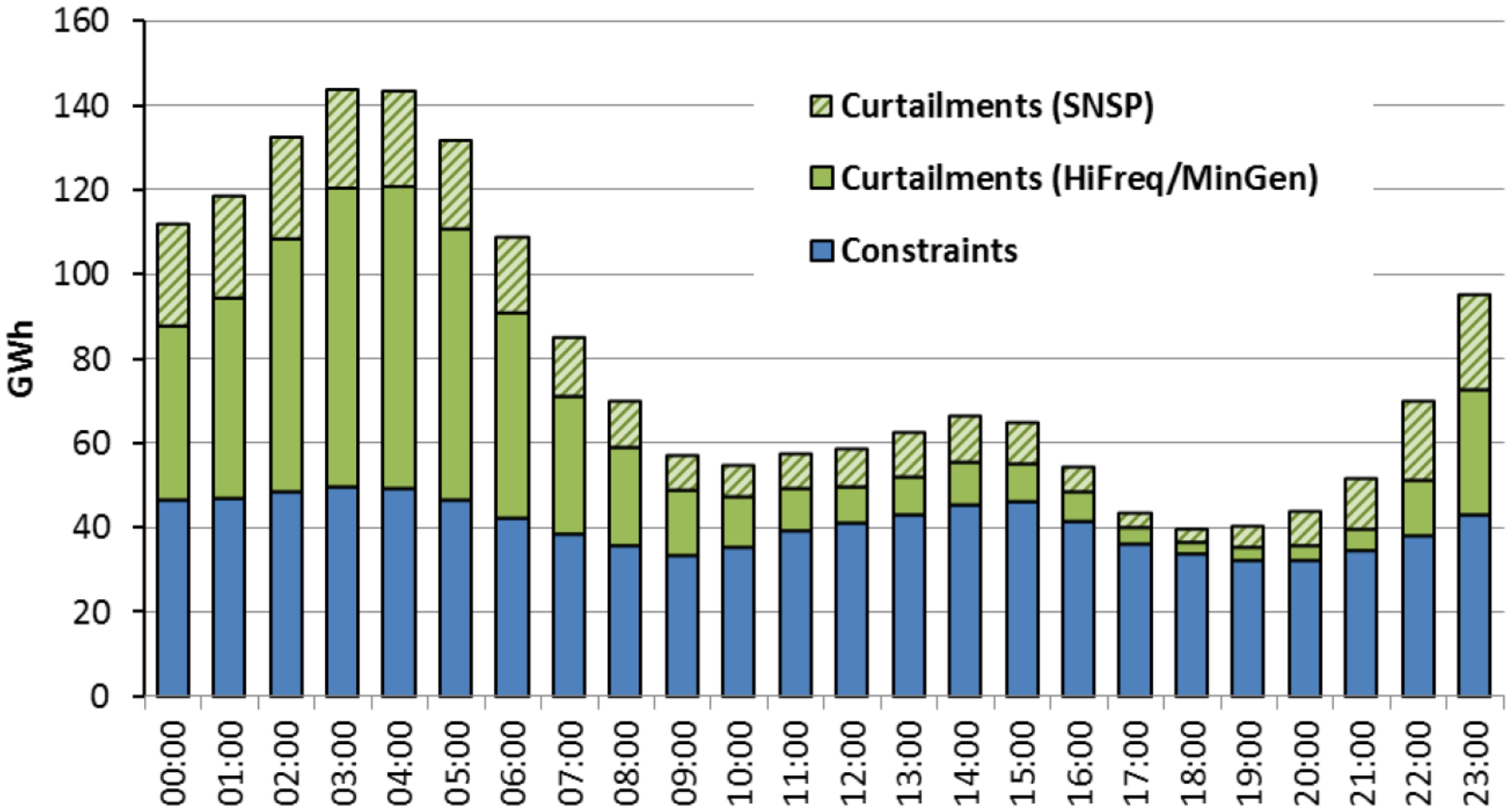
Facilitation of Renewables Studies



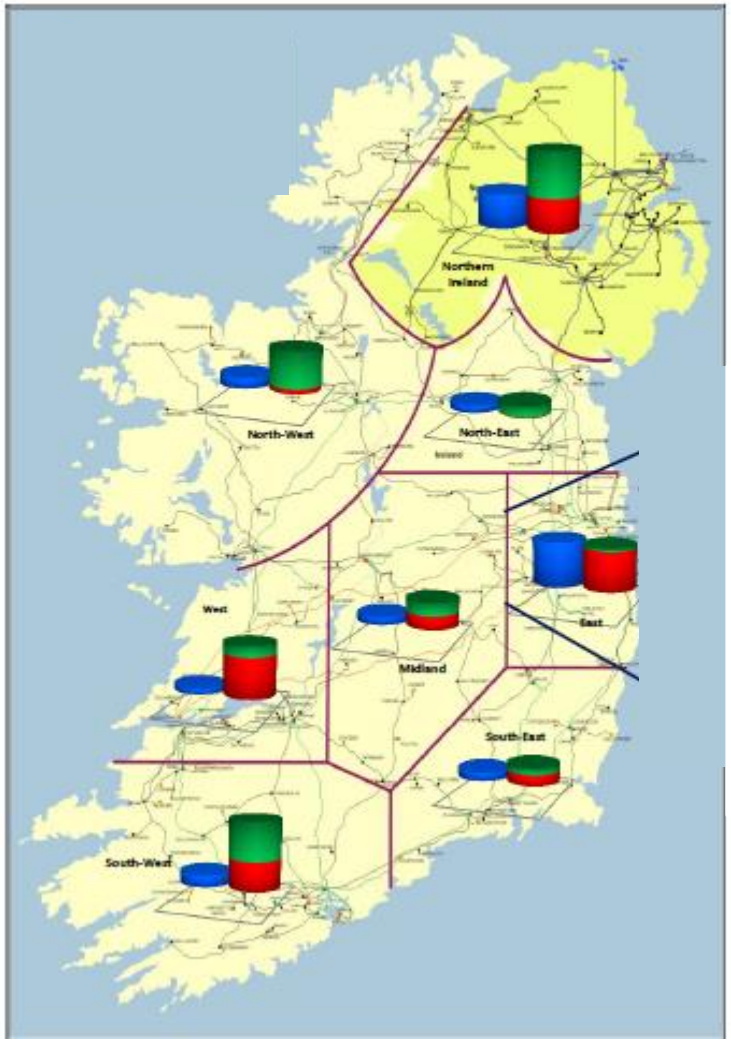
EIRGRID

UCD DUBLIN

Wind Dispatch Down 2020



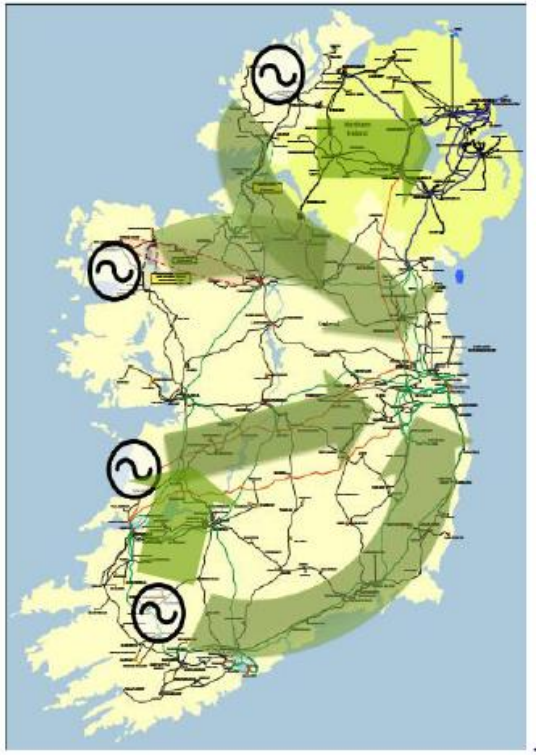
Load vs. Generation Distribution



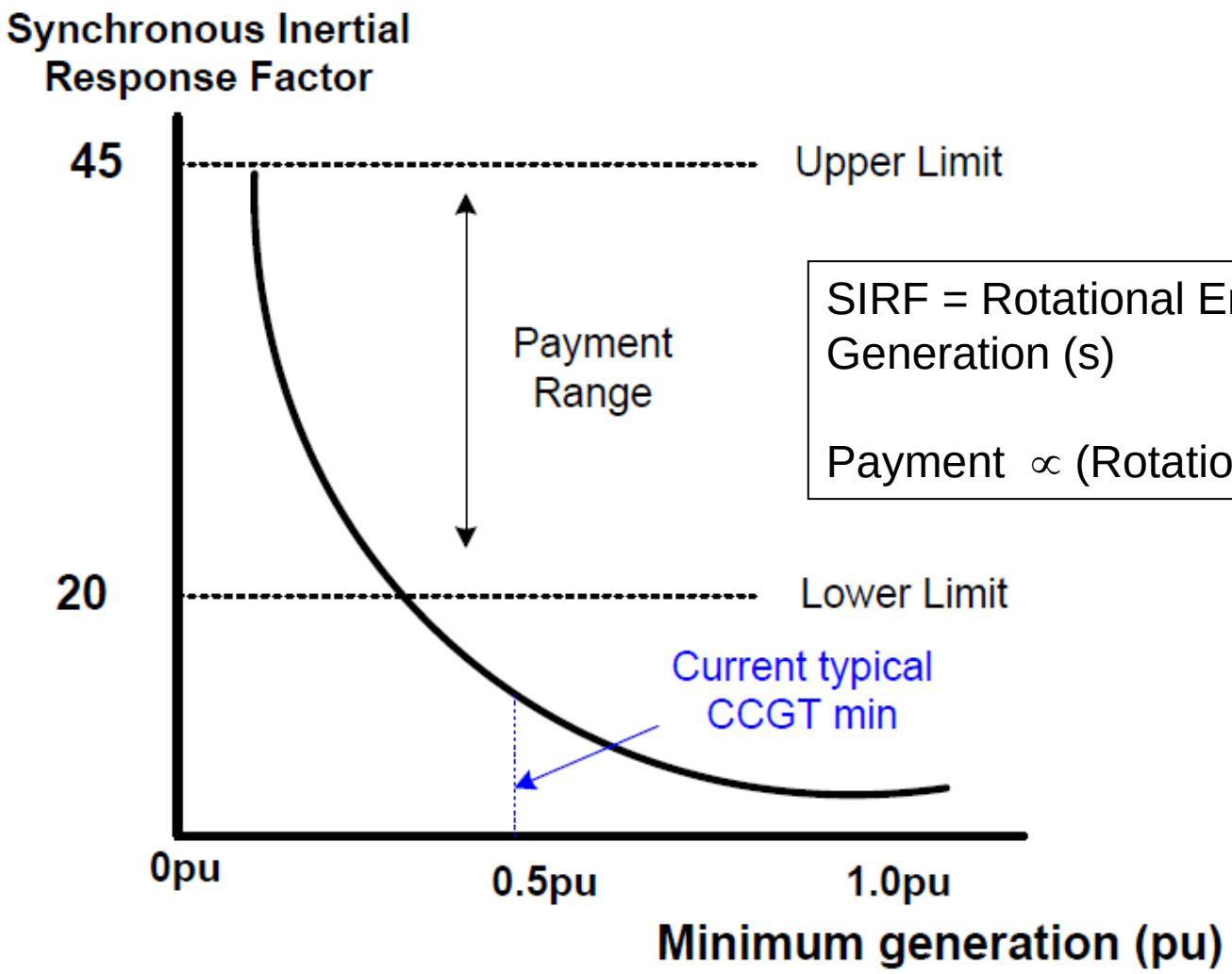
Demand

Conventional Generation

Renewable Generation



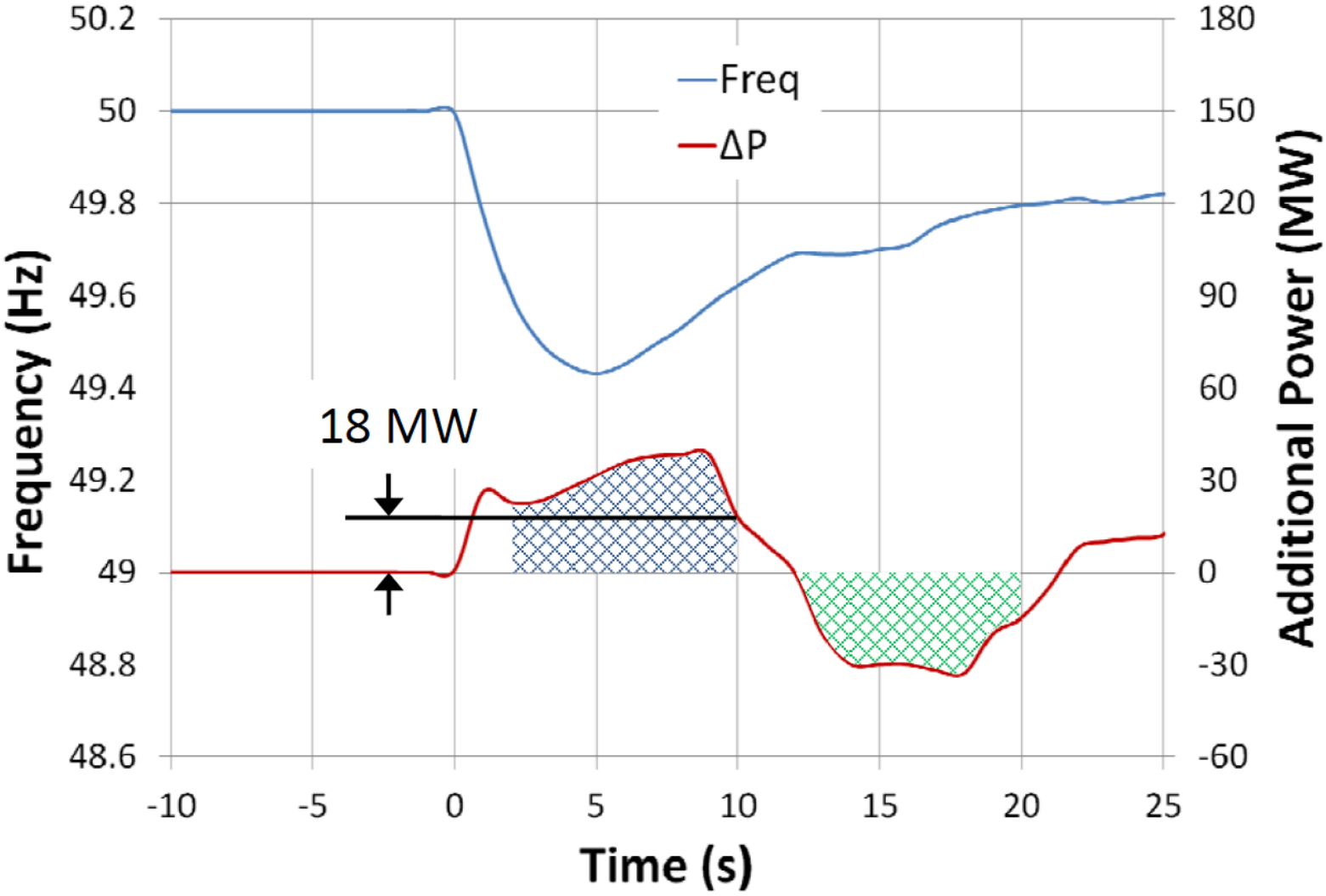
Synchronous Inertial Response



SIRF = Rotational Energy / Min Stable Generation (s)

Payment $\propto$ (Rotational Energy x SIRF)

Fast Frequency Response



Dynamic Reactive Response