

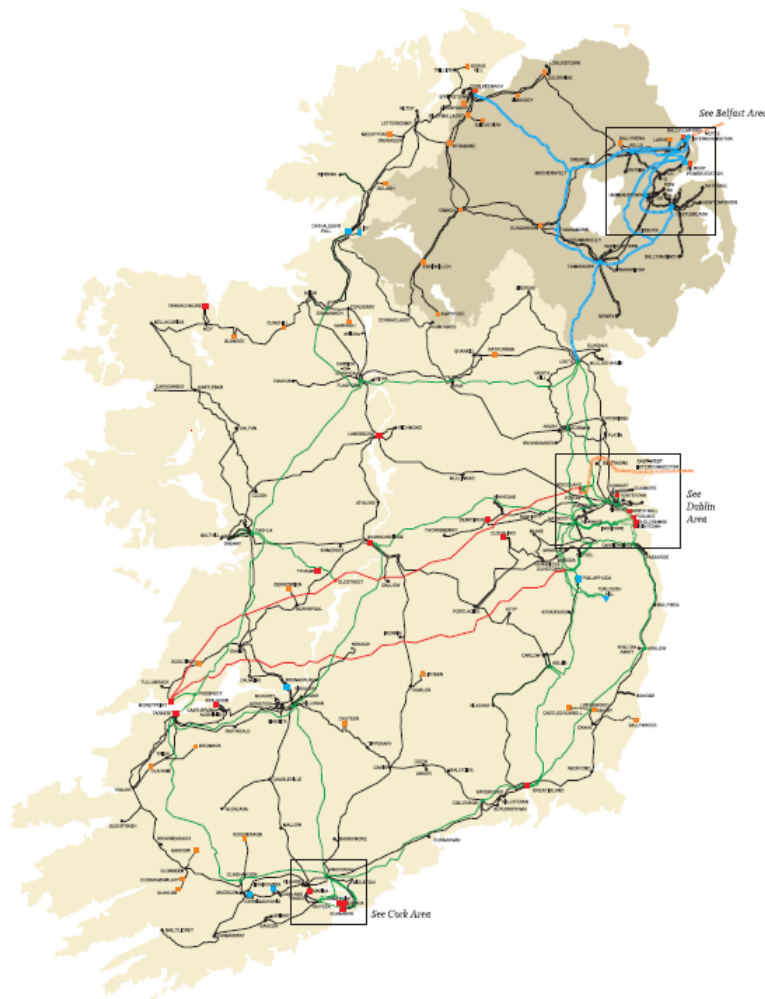
Present and Future Operation of the Ireland Power System

Damian Flynn

University College Dublin

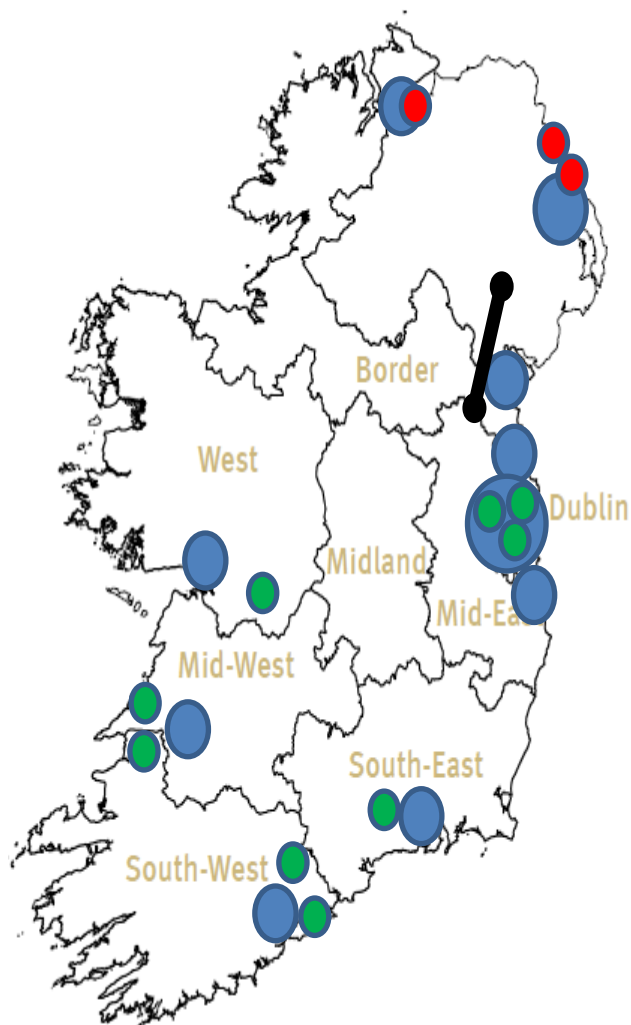


All-Island Power System



- 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

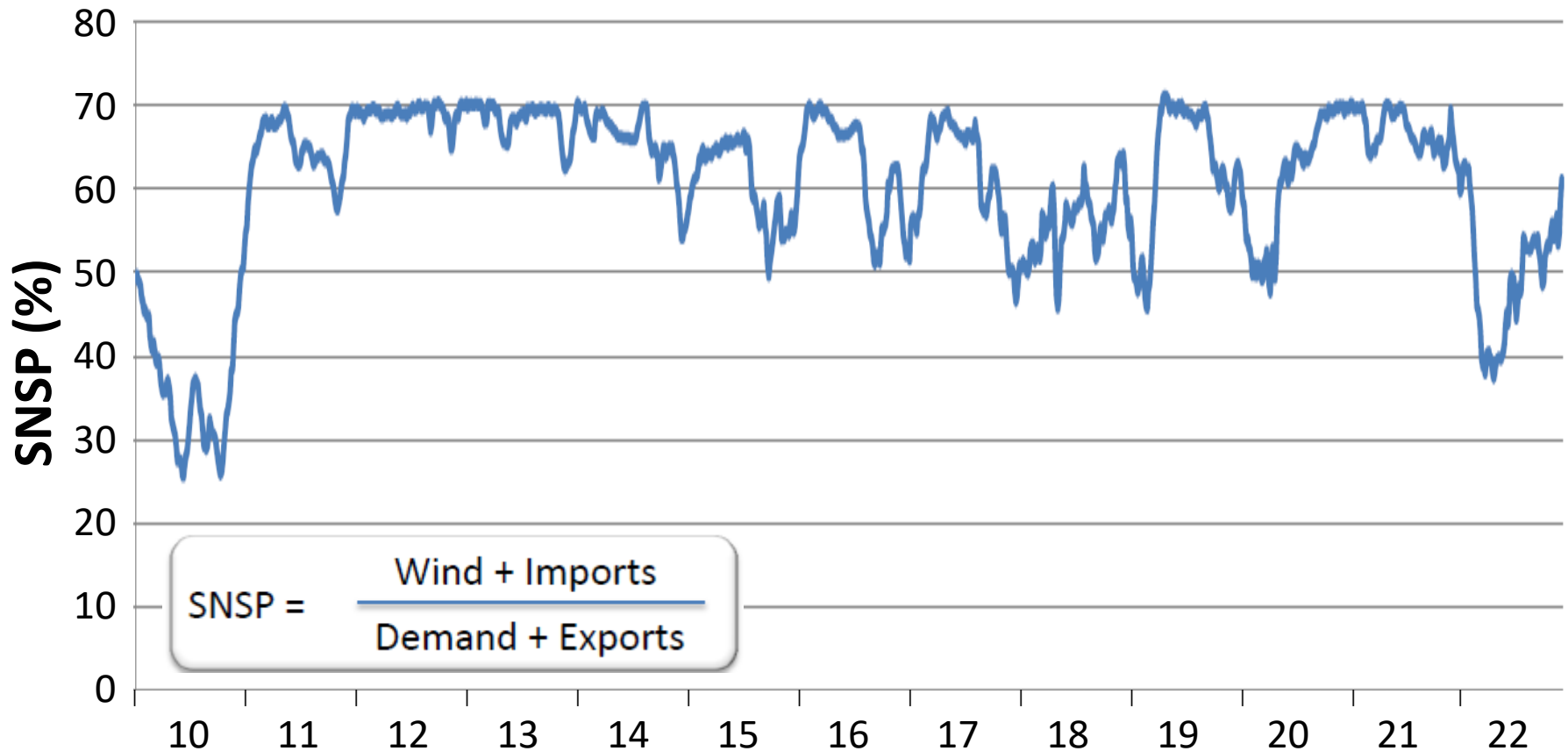
SNSP $\leq 70\%$ (75%)

RoCoF ≤ 0.5 Hz/s (1.0 Hz/s)

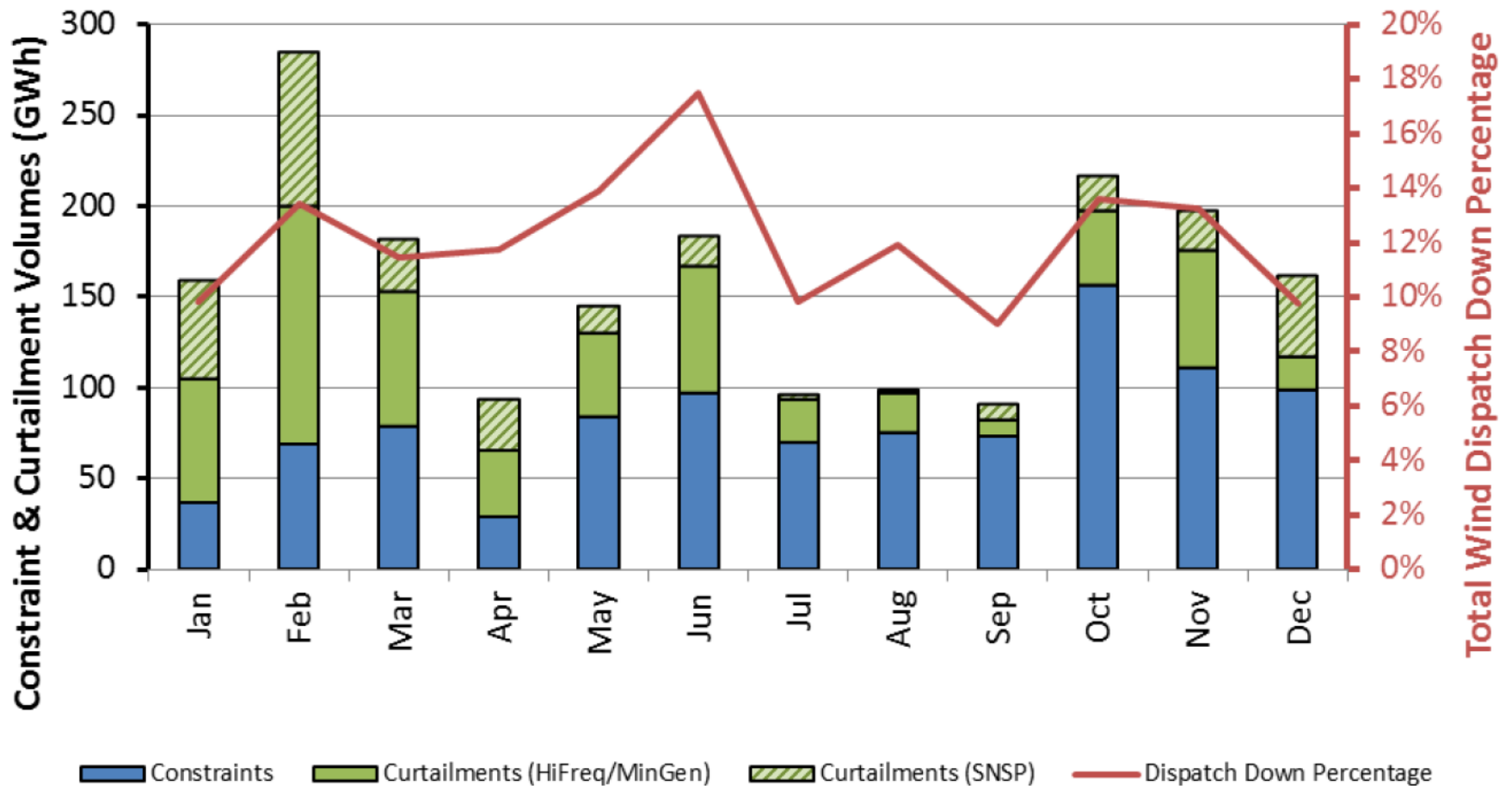
Inertia $\geq 23,000$ MWs

System Non-Synchronous Penetration

February 2021

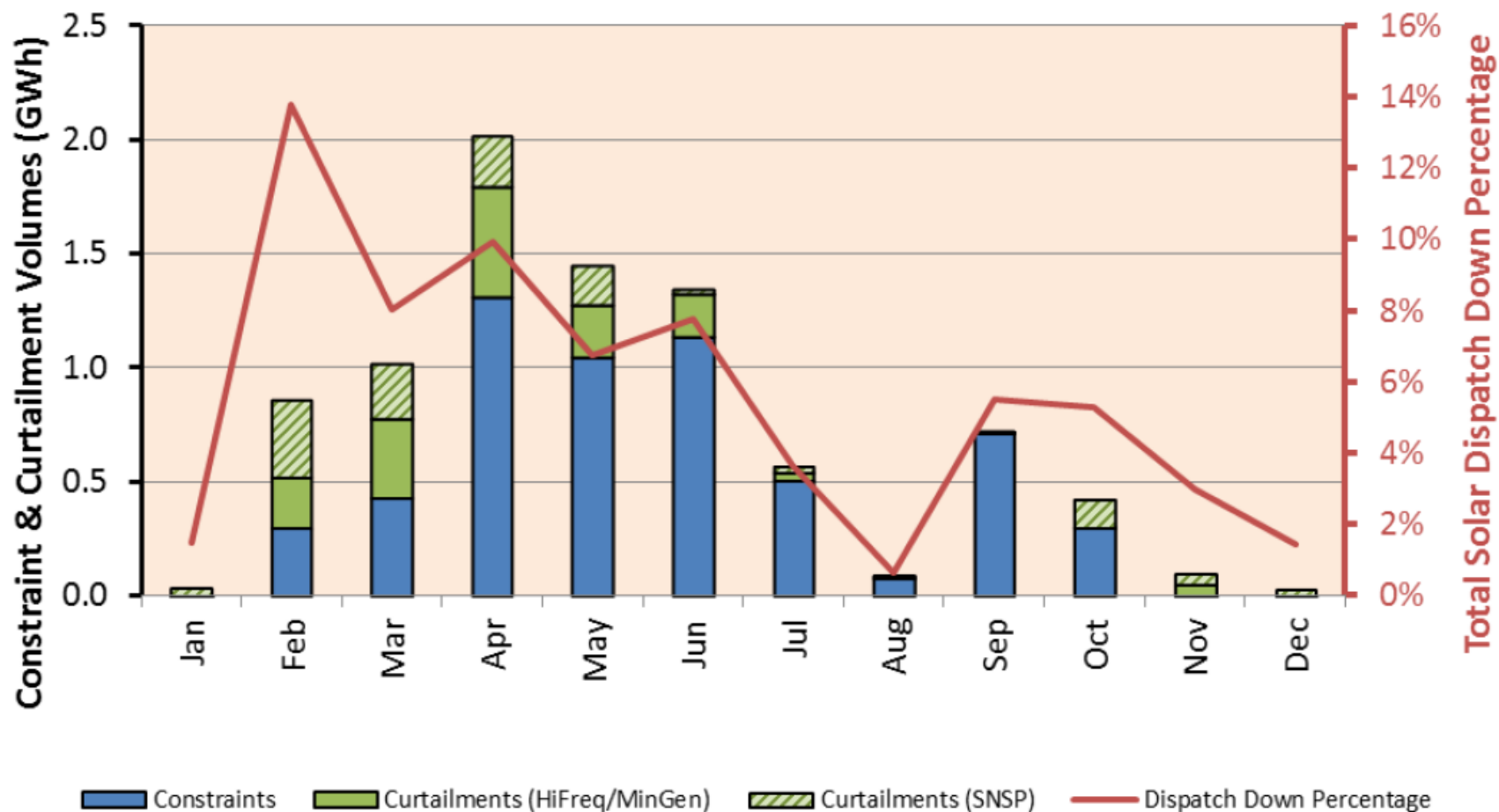


Wind Dispatch Down 2020



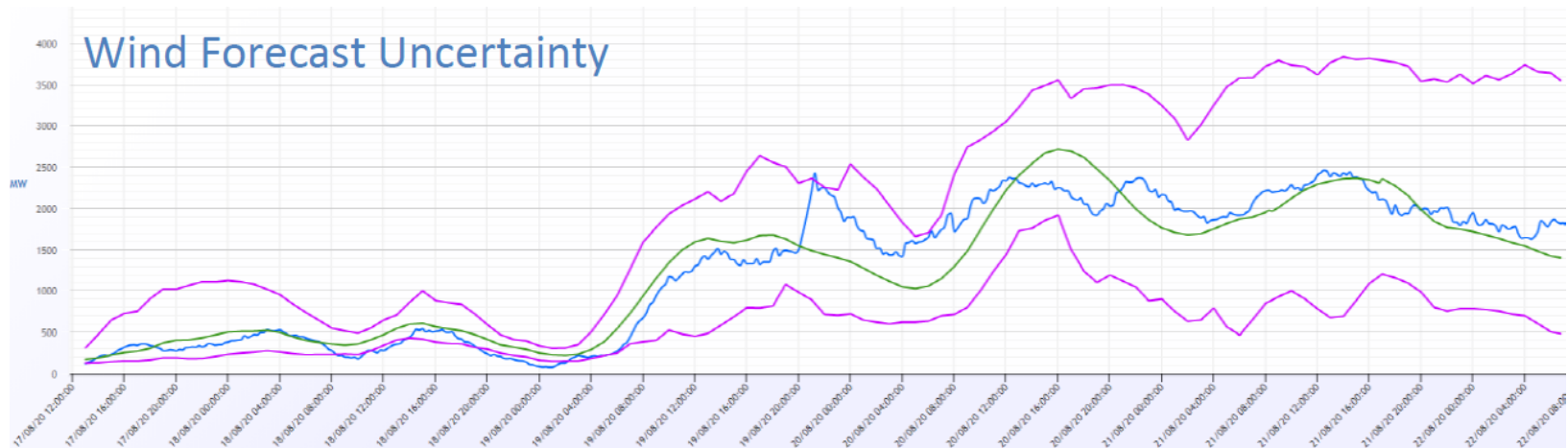
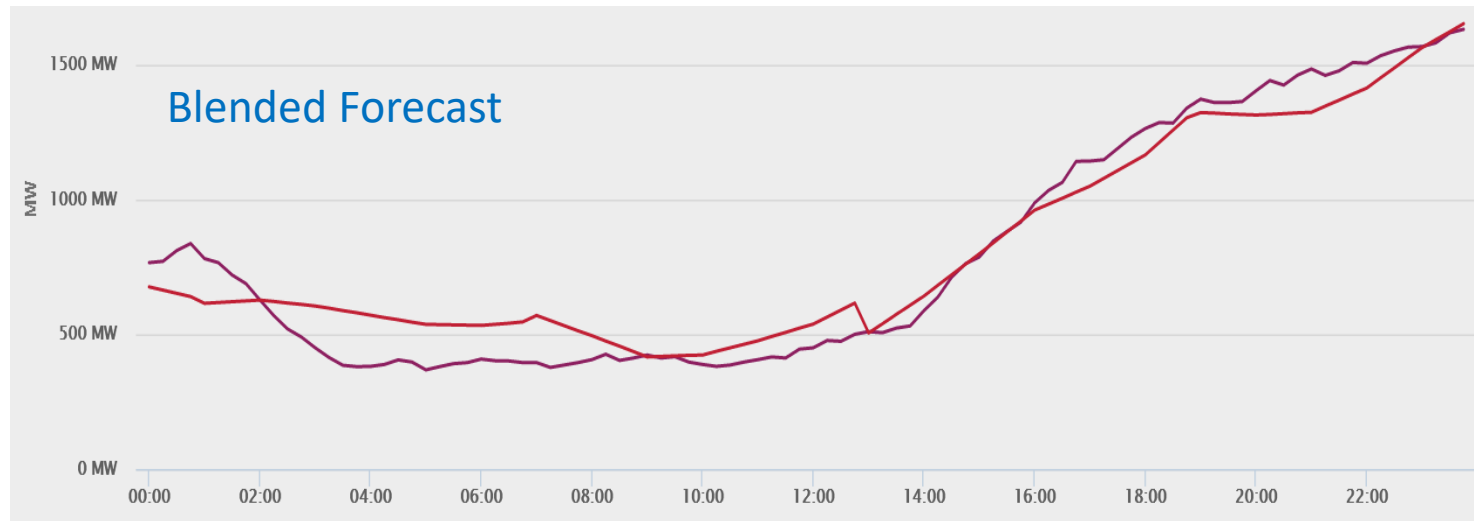
Solar PV Dispatch Down 2020

Northern Ireland



Wind Forecasting

- Primary and secondary wind vendors appointed



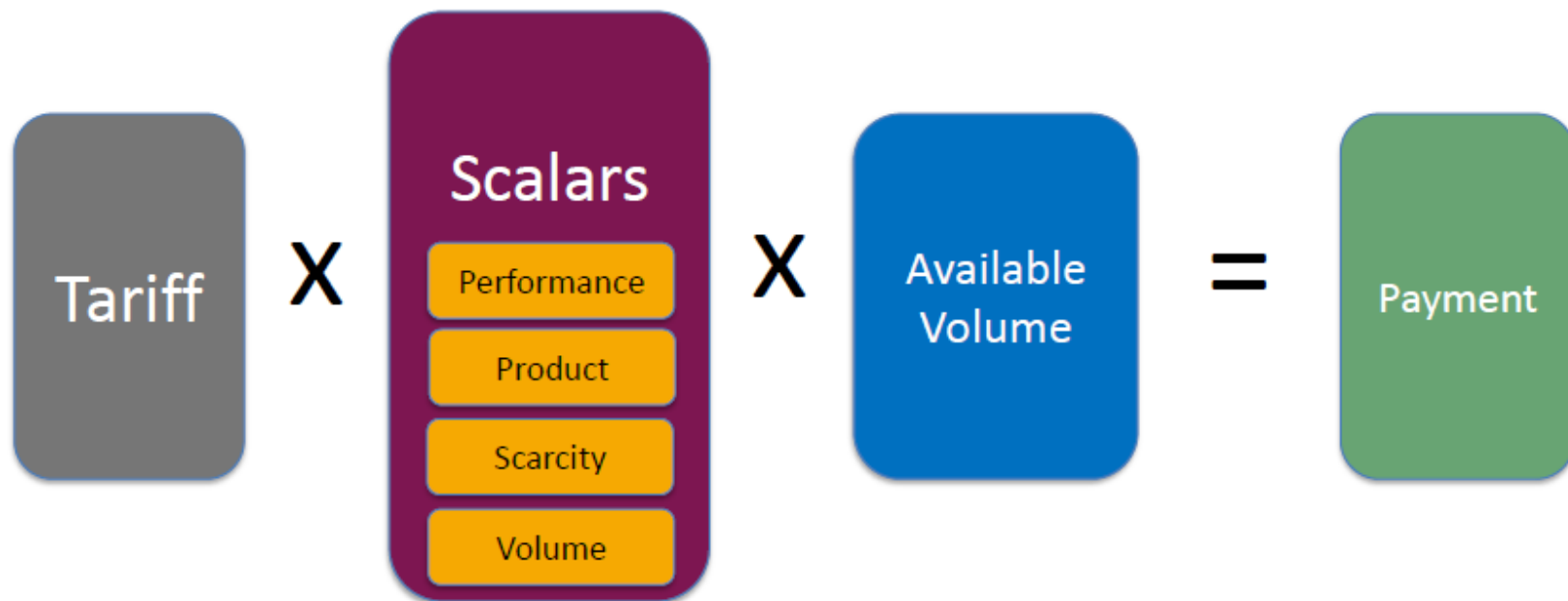
System Services Categories

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*

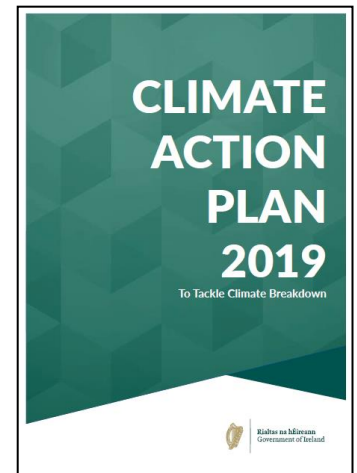
Payment Arrangements



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 ?

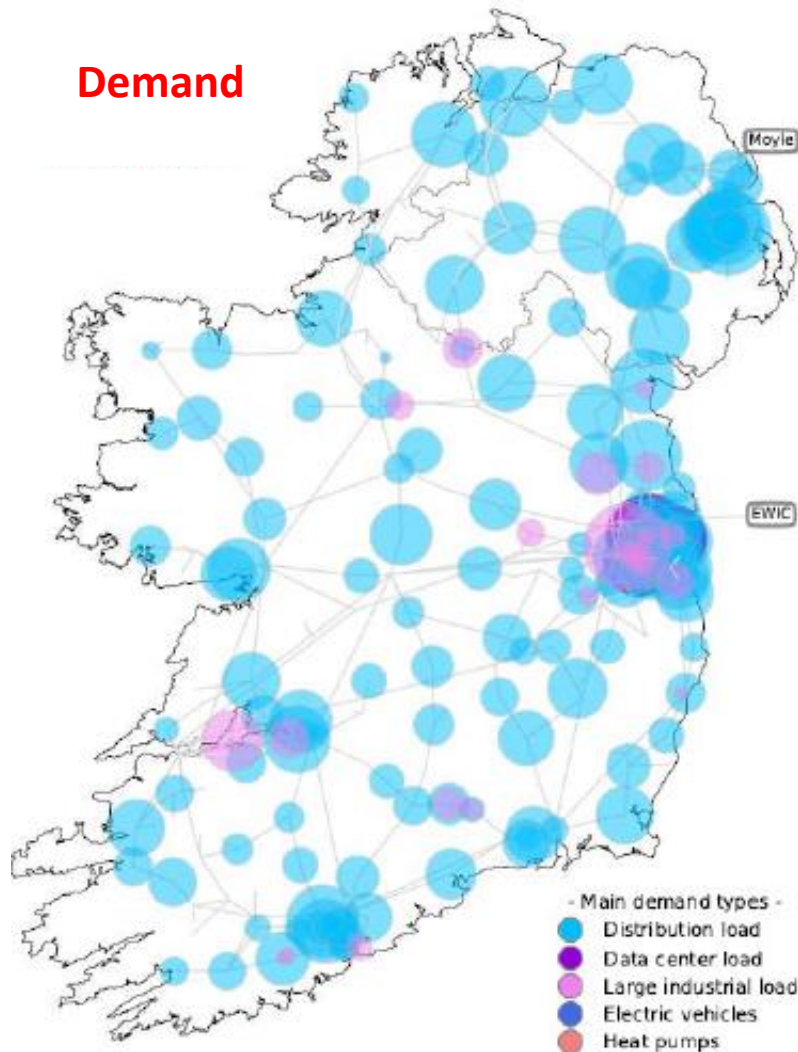
Climate Action Plan 2019

- 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**

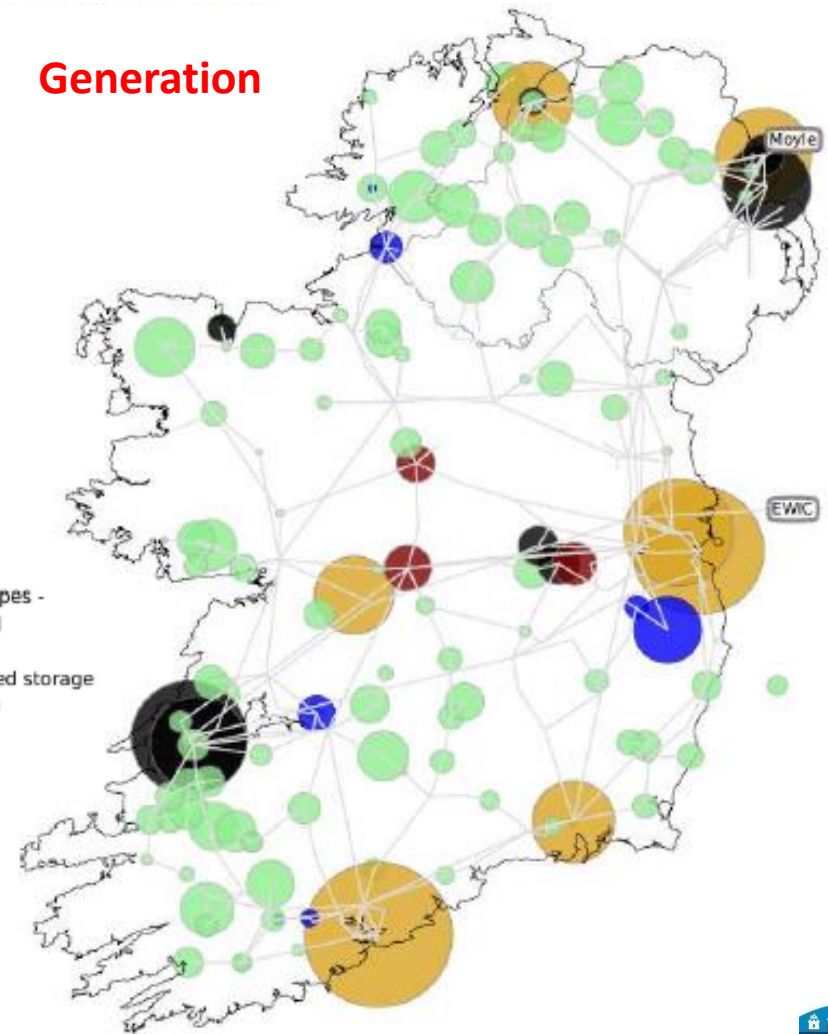


Demand vs. Generation 2020

Demand

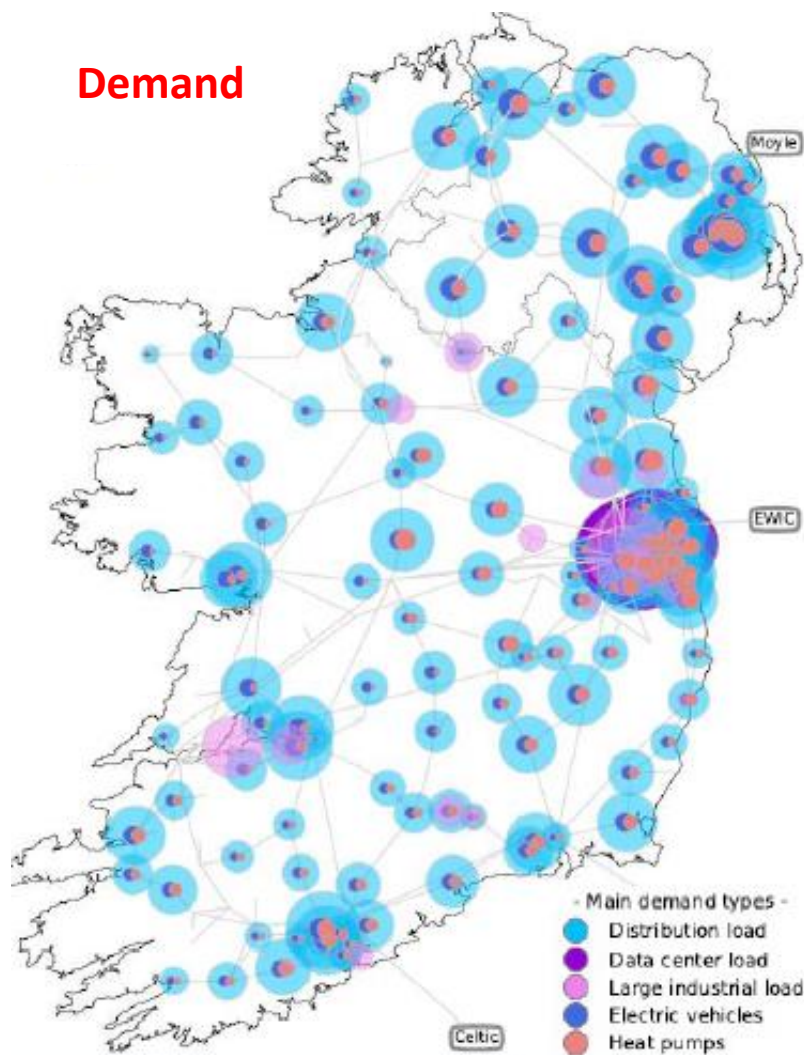


Generation

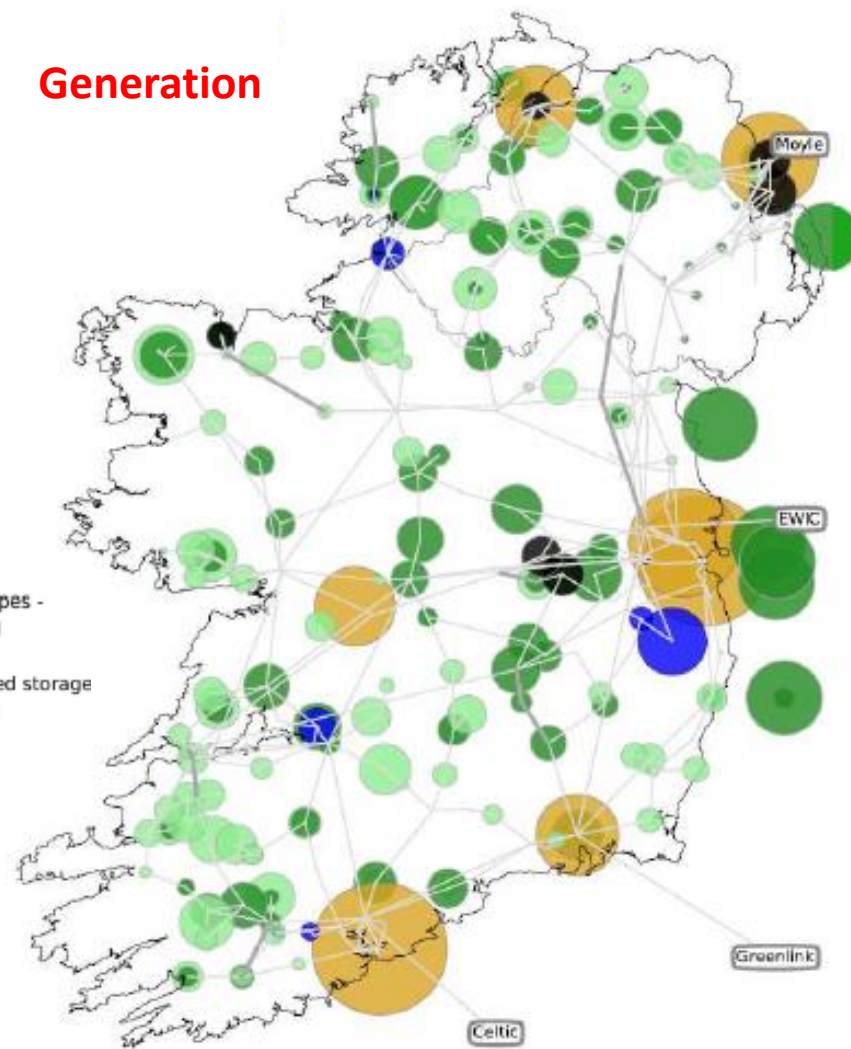


Demand vs. Generation 2030

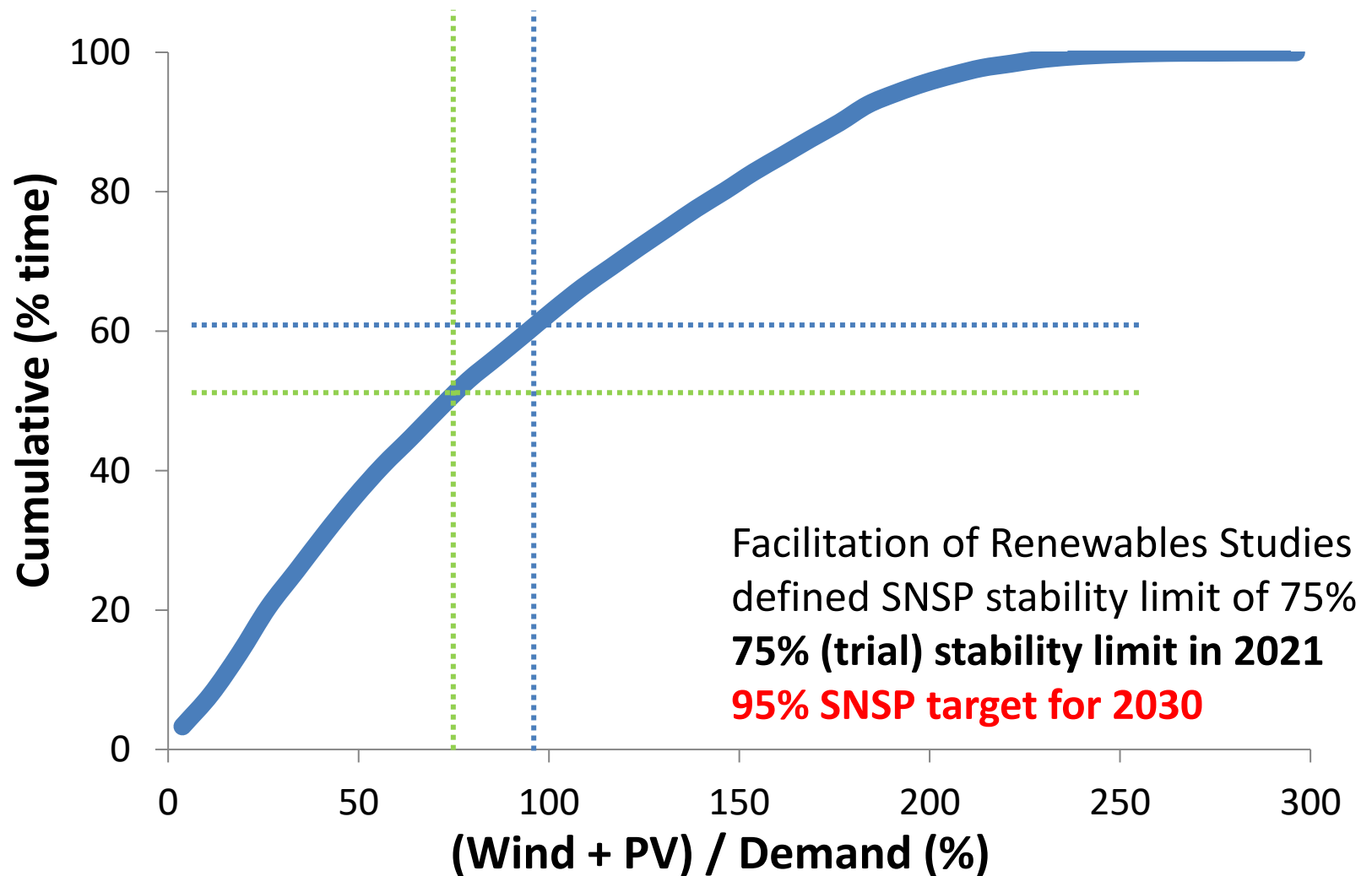
Demand



Generation



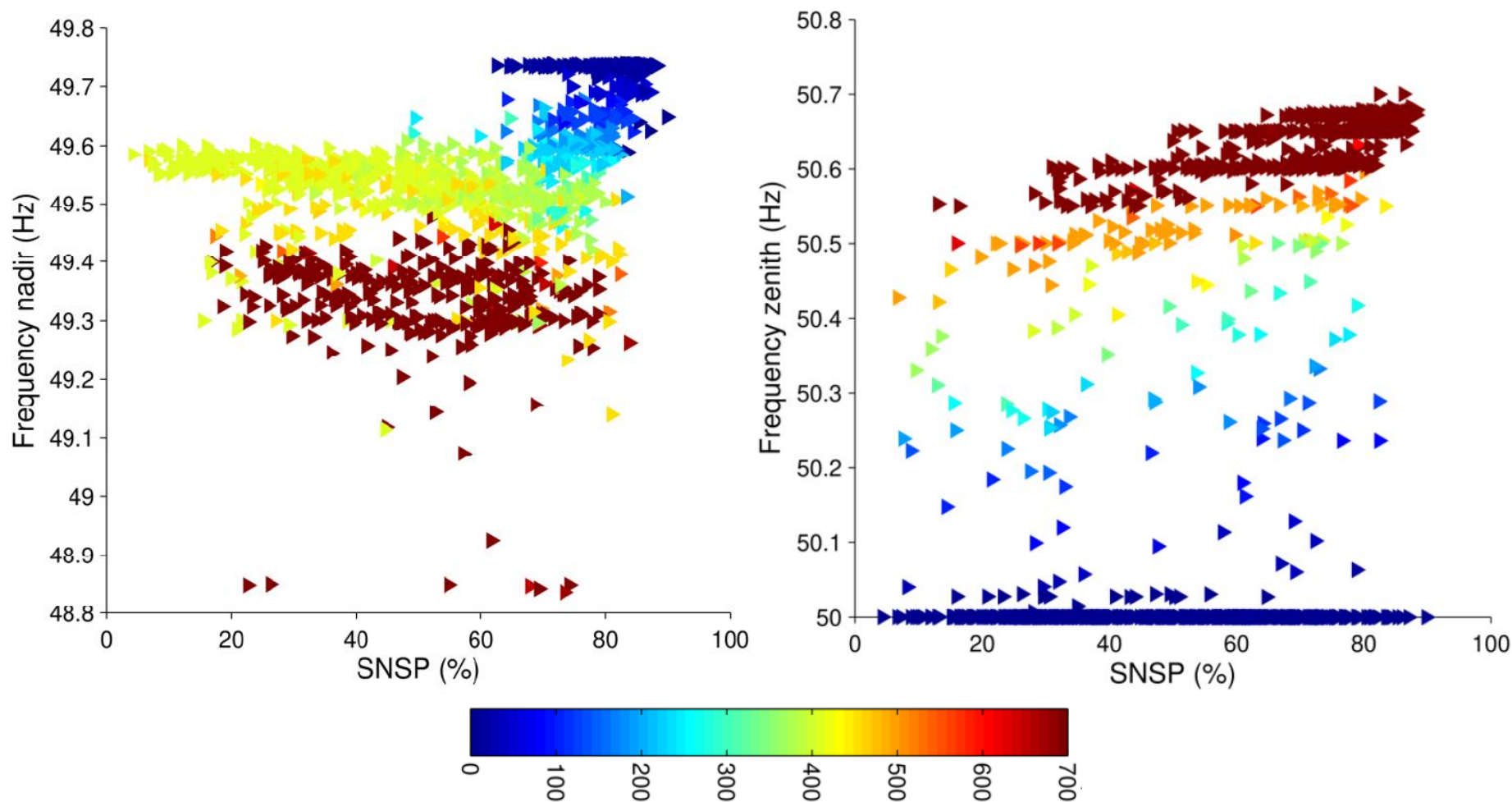
Ireland + N. Ireland 2030



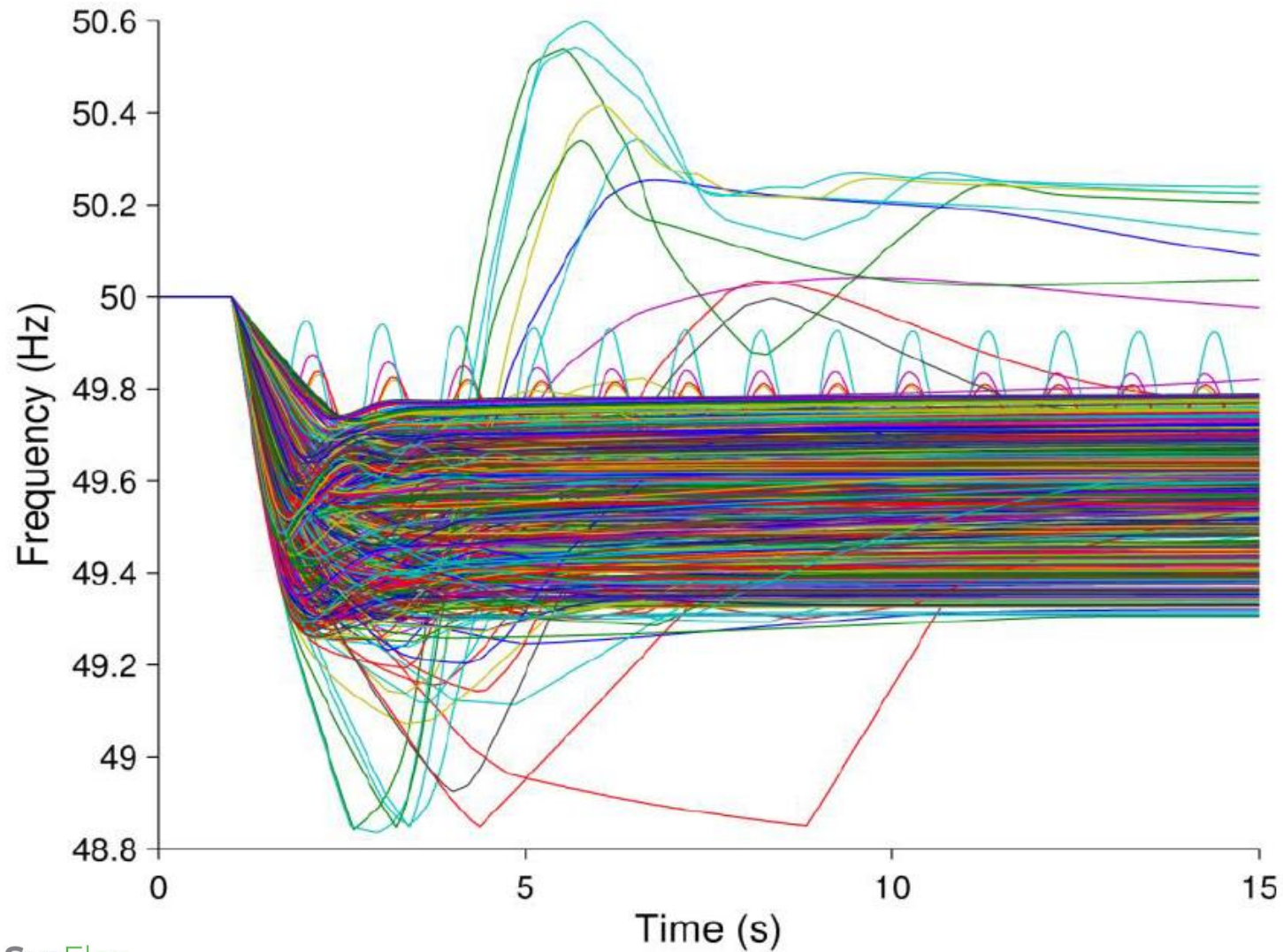
System Scarcities 2030

	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

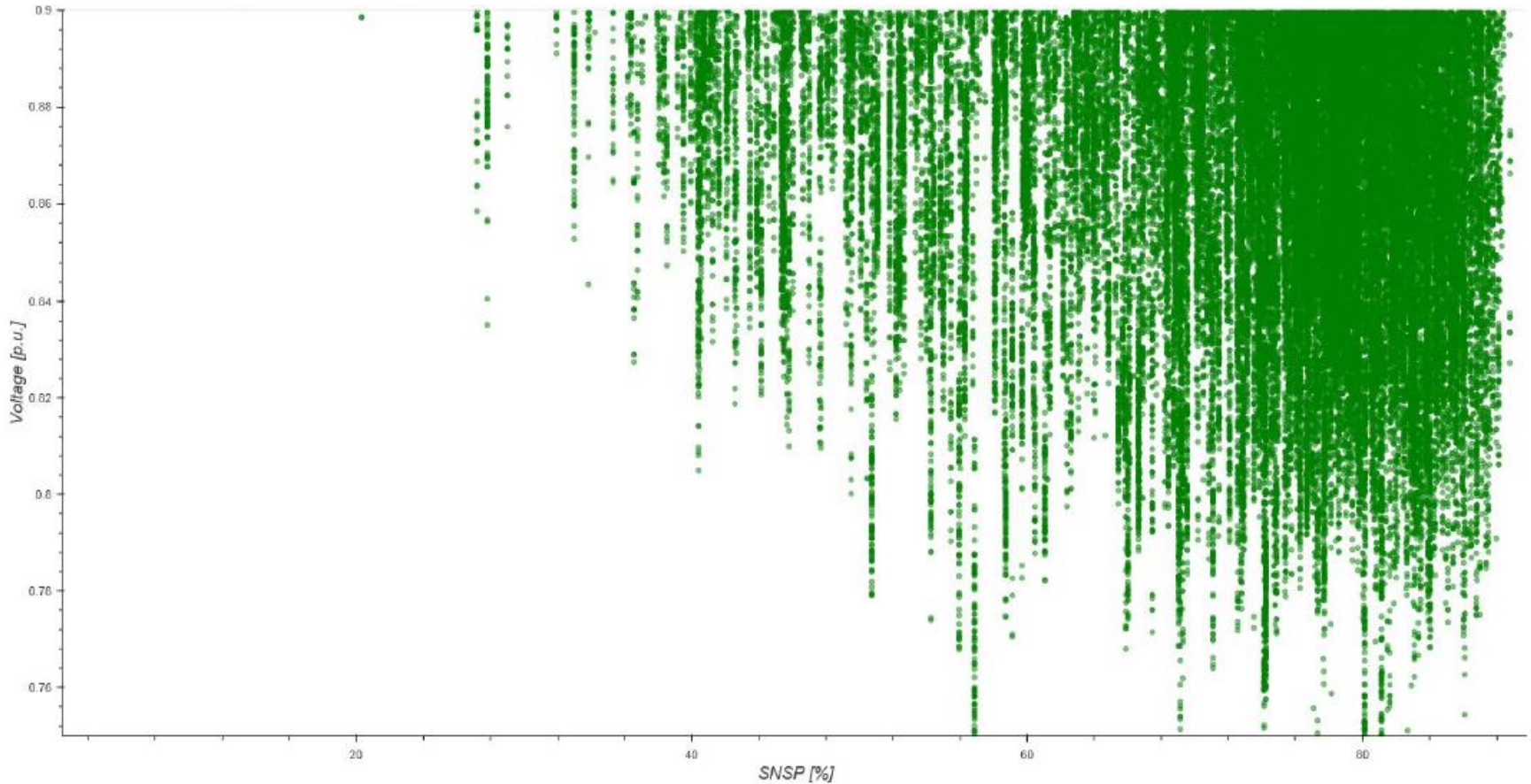


Loss of Largest Infeed



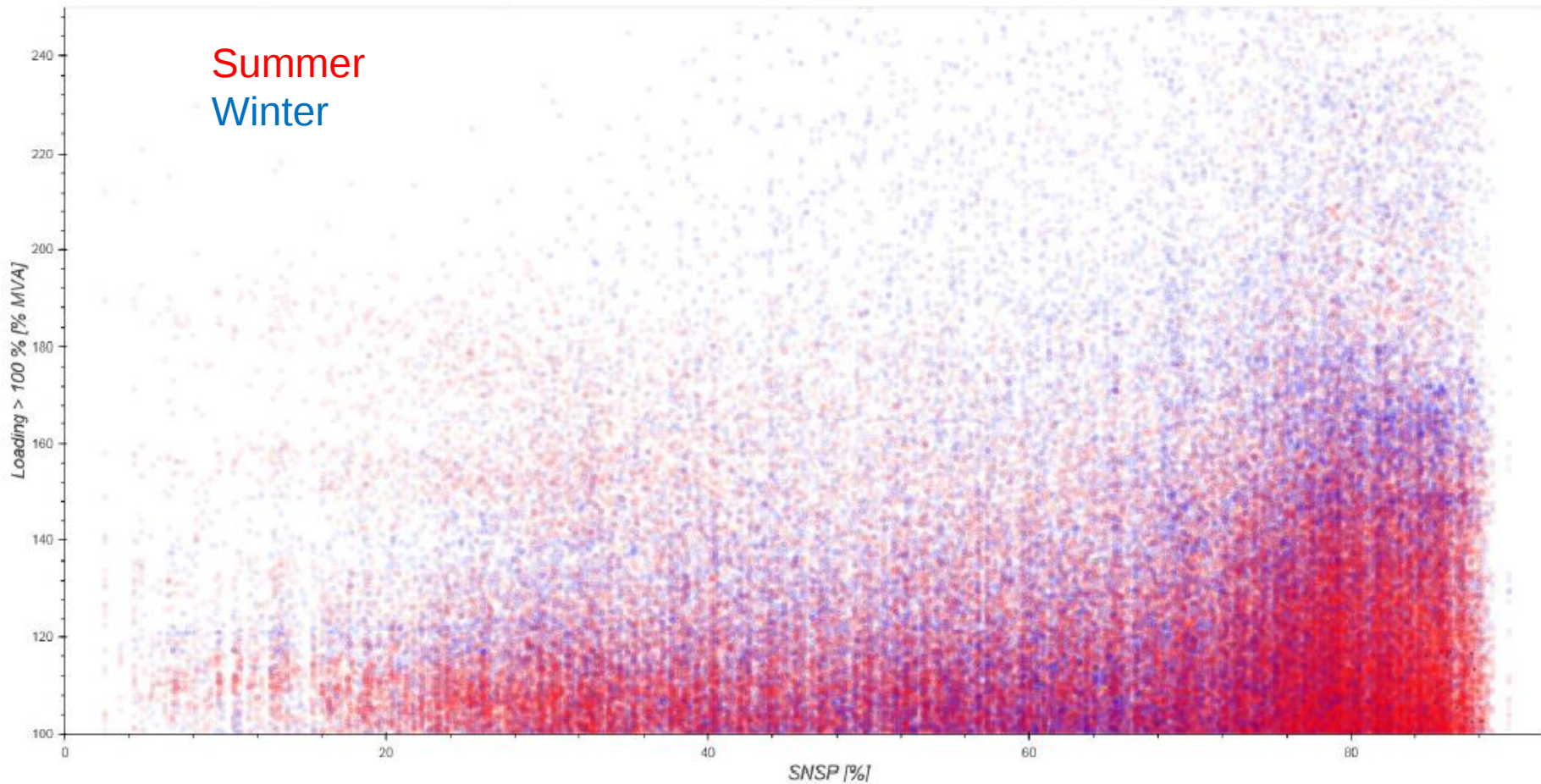
N-1 Low Voltage Scenarios

Shortage of steady-state reactive power capability



N-1 Transmission Network Overloading

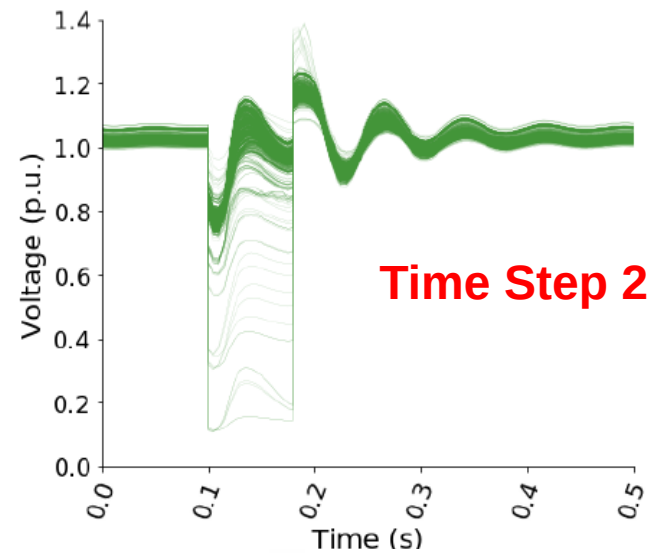
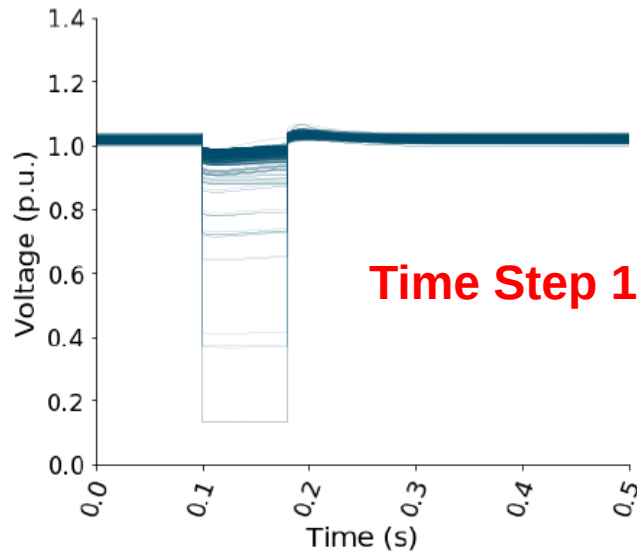
Desirability for congestion related system service?



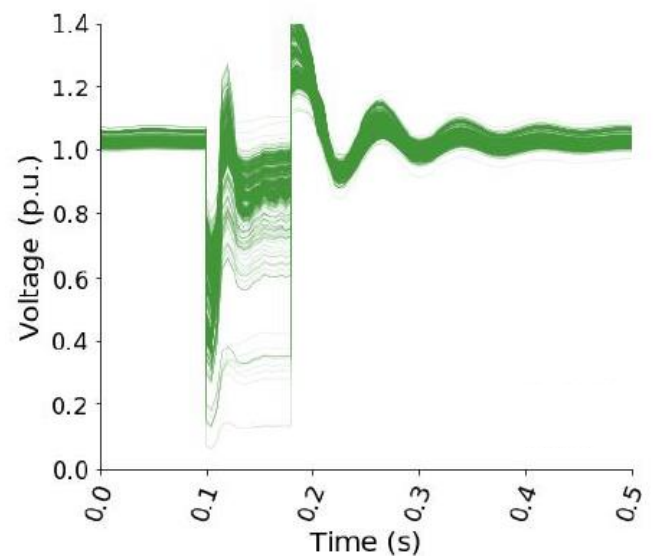
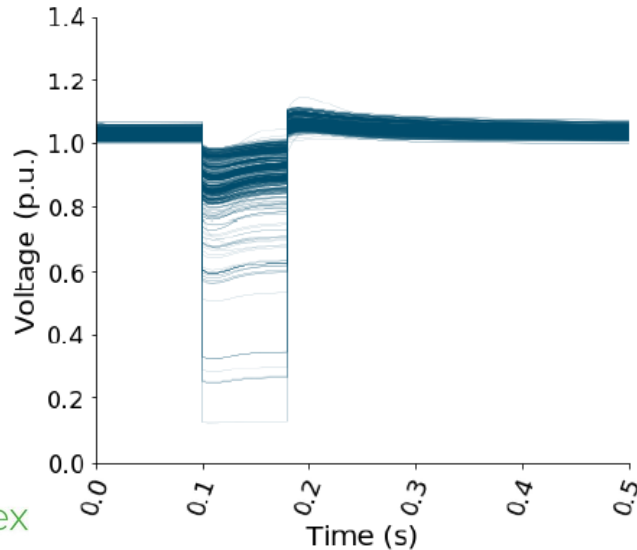
Bolted 3-Phase Line Faults

Requirement for dynamic reactive response capability

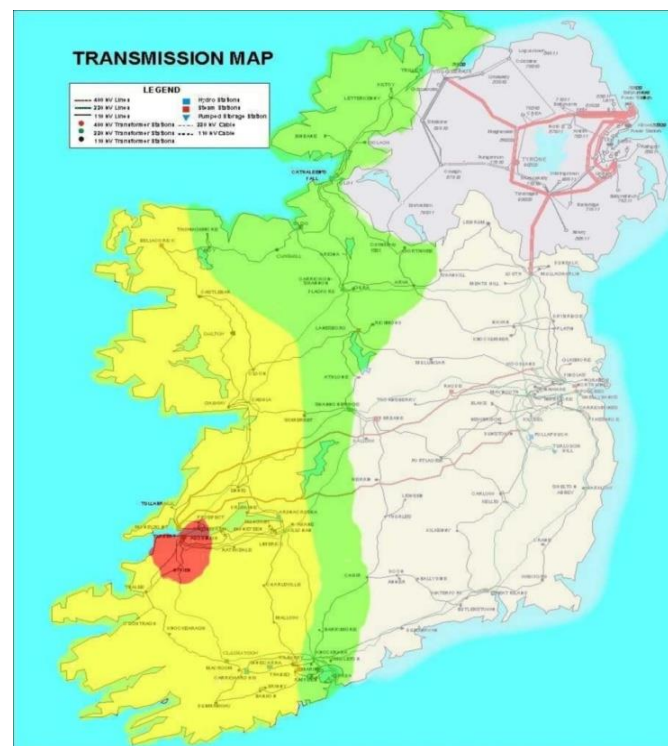
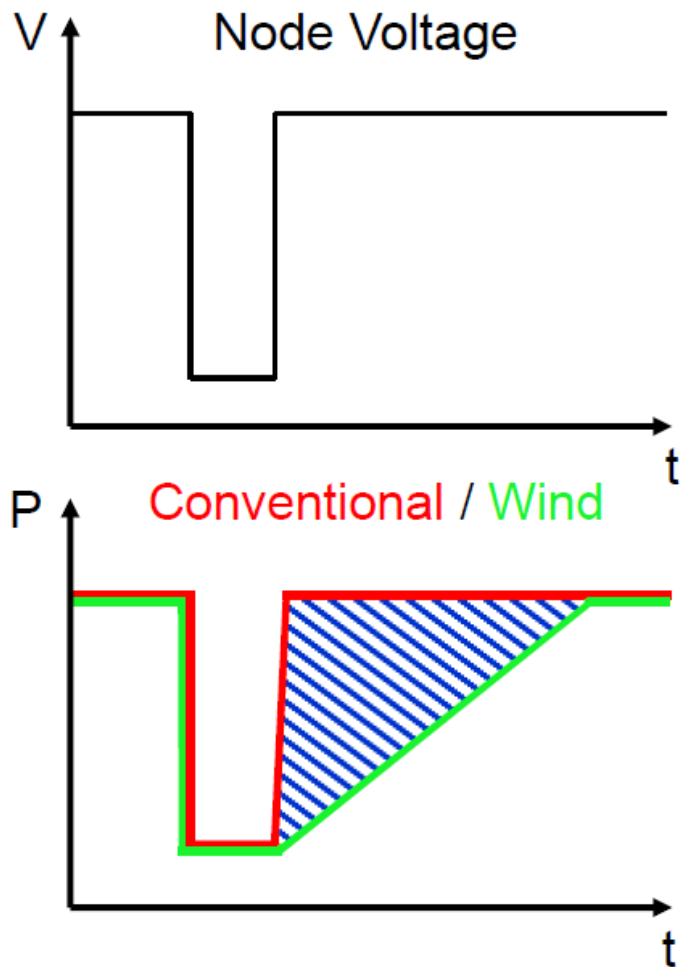
**Fault
Location
A**



**Fault
Location
B**



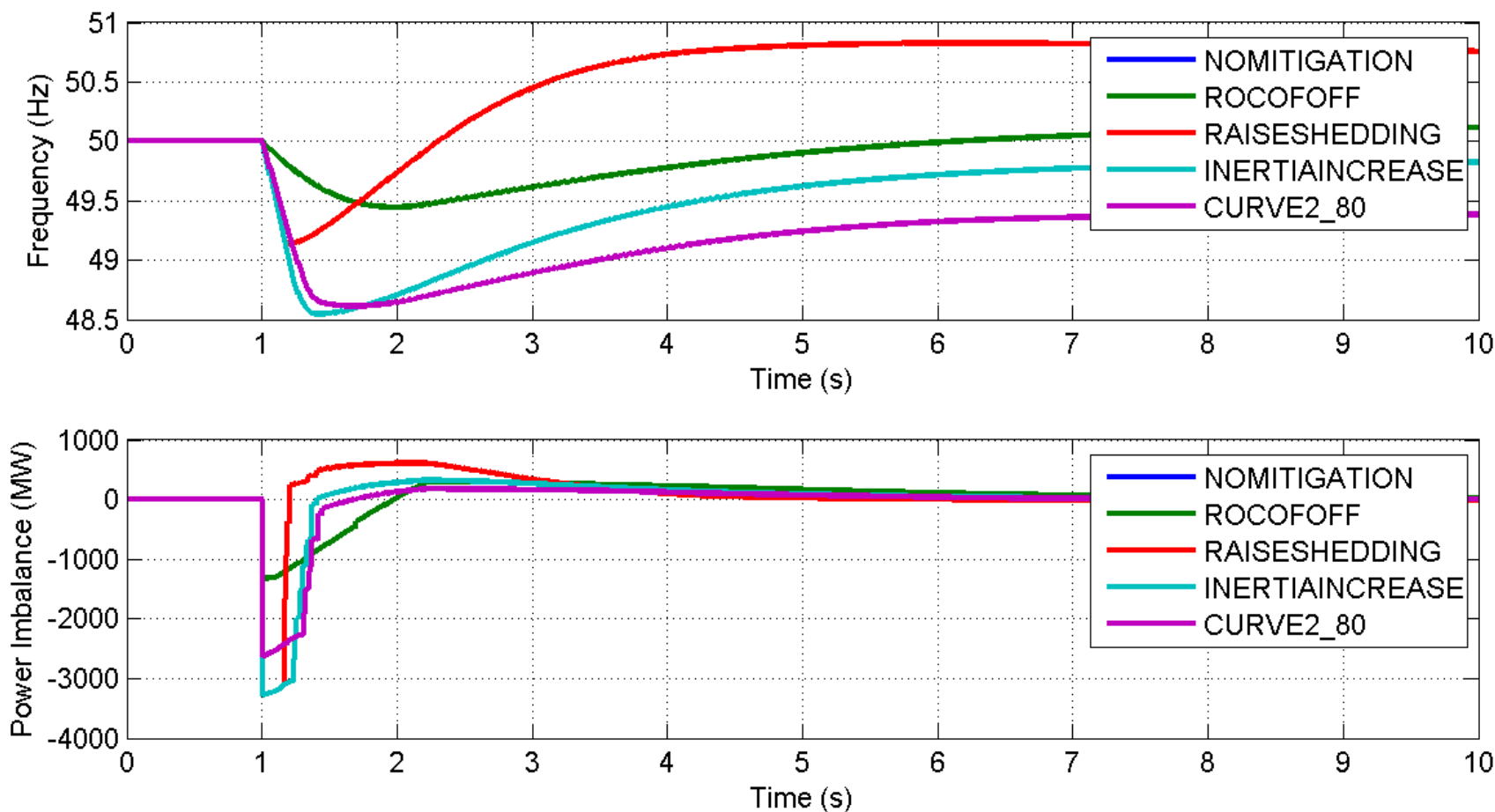
Voltage Dip-Induced Frequency Dips



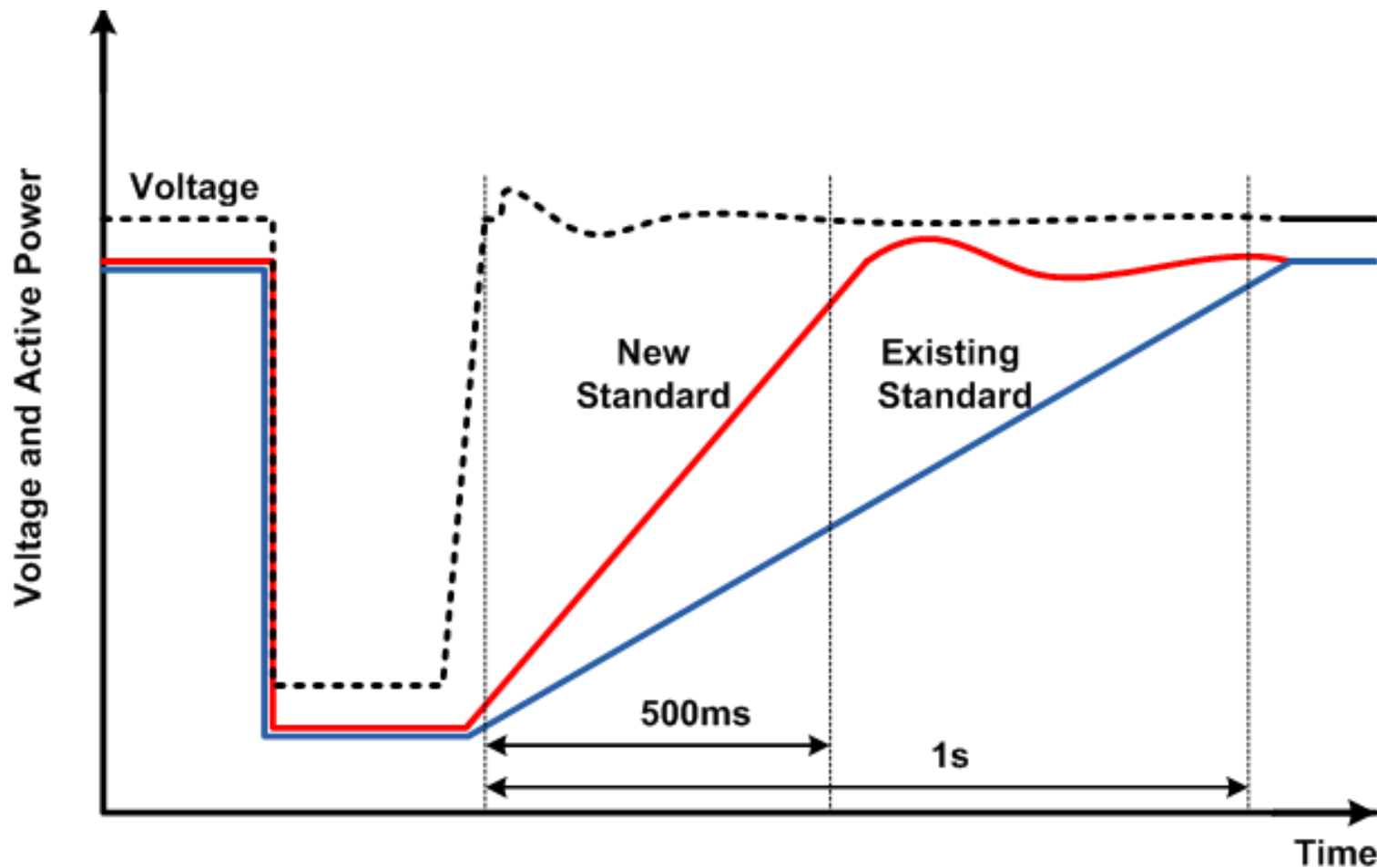
Voltage Profile

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

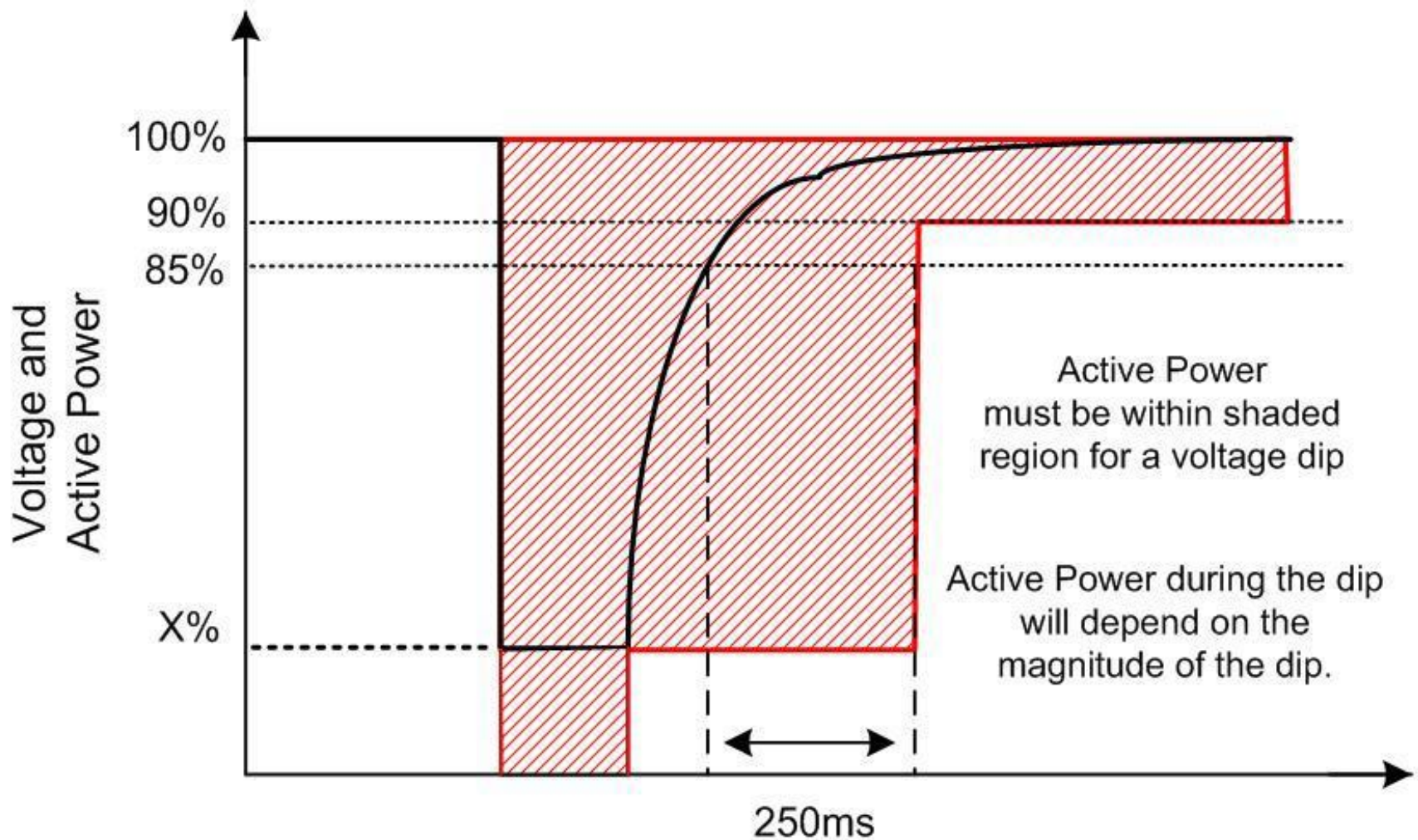
Voltage Dip-Induced Frequency Dips



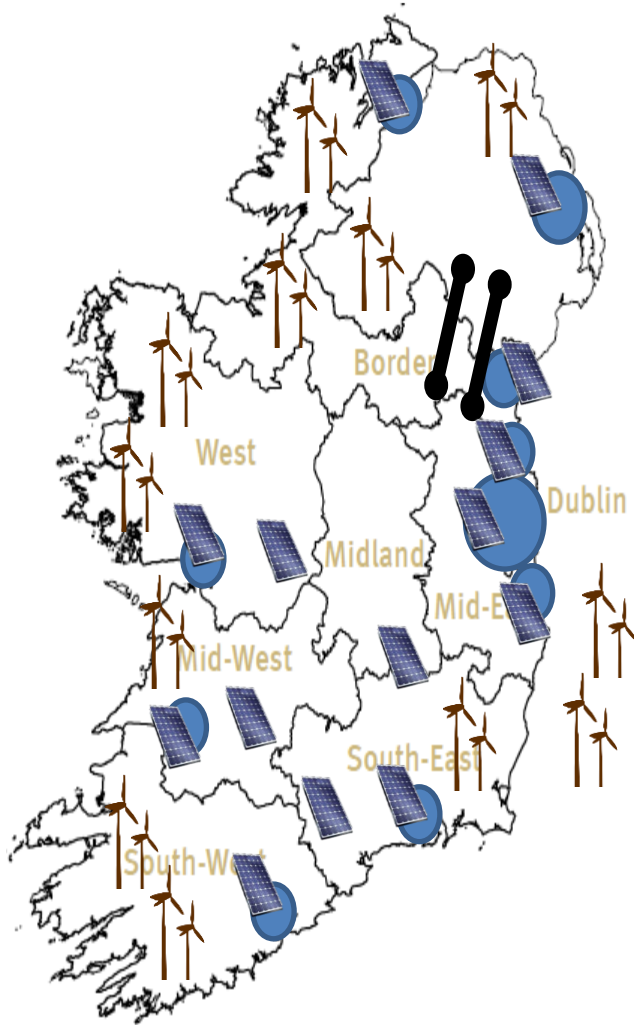
Post-Fault Active Power Recovery



Post-Fault Active Power Recovery



100% SNSP Scenario



● Major load centres

▮ PV generation

↑ Wind generation

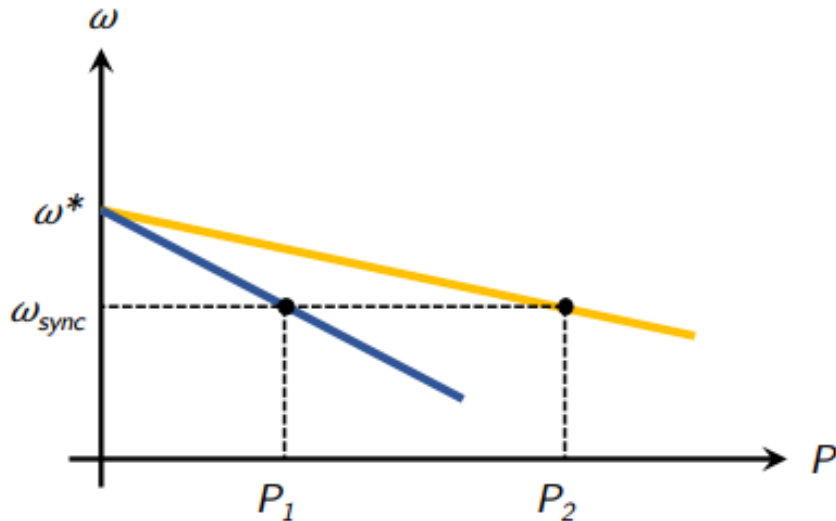
System grid-forming ratio

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

System non-synchronous penetration

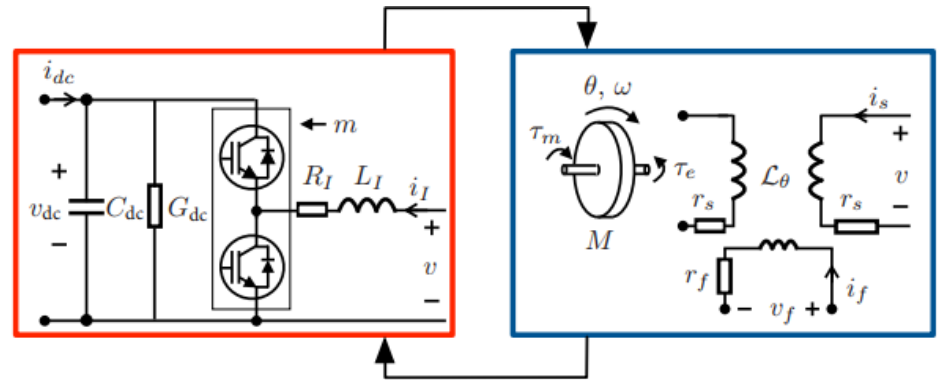
$$SNSP = \frac{P_W + P_{HVDC(\text{imp})}}{P_L + P_{HVDC(\text{exp})}}$$

Grid-Forming Control Strategies

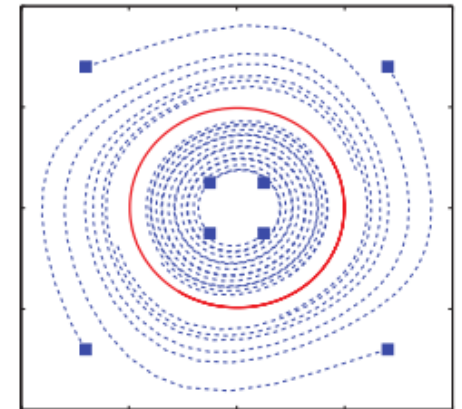
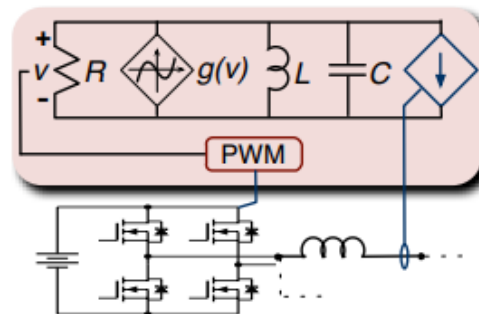


Droop control

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



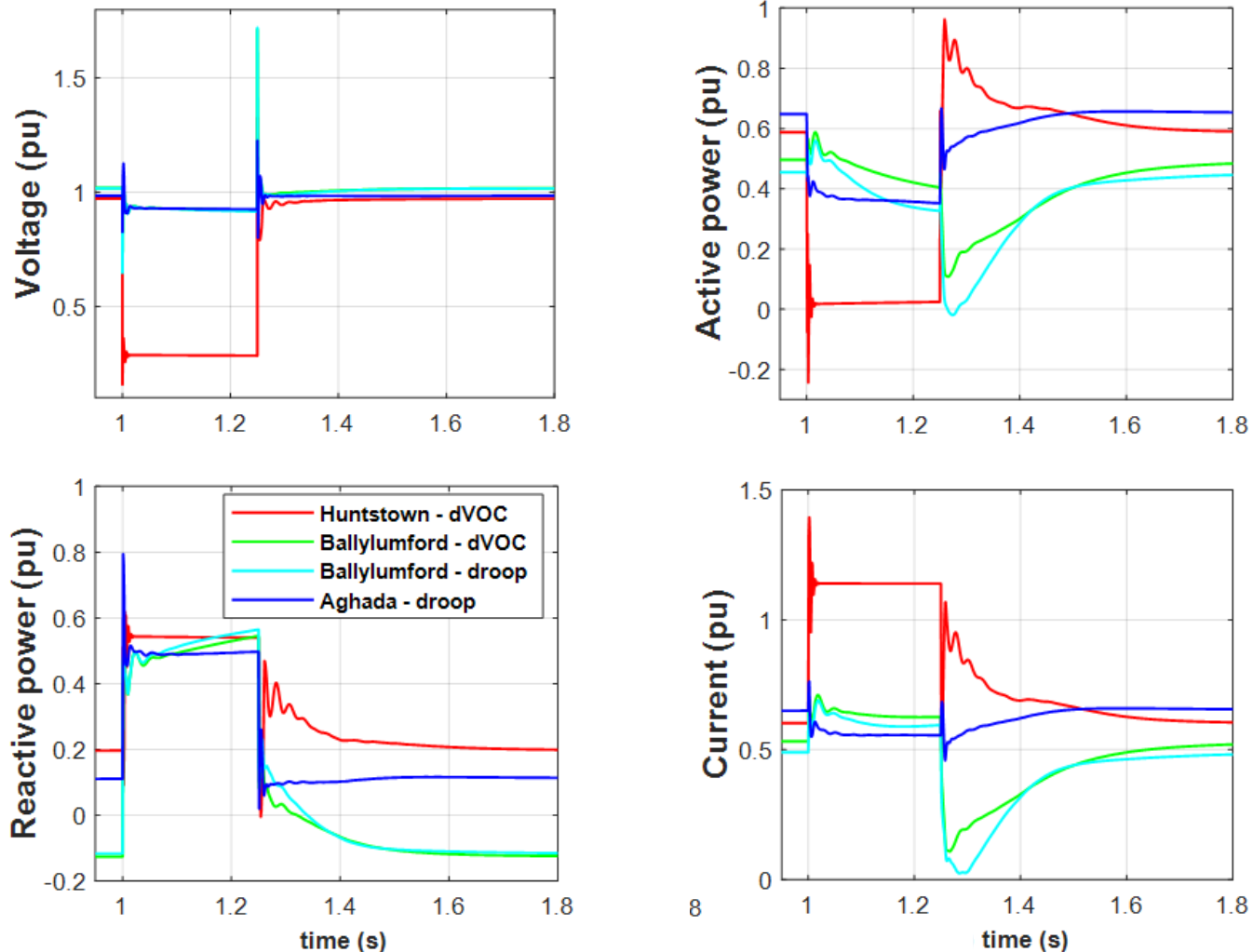
Synchronous machine matching



Virtual oscillator control (VOC)

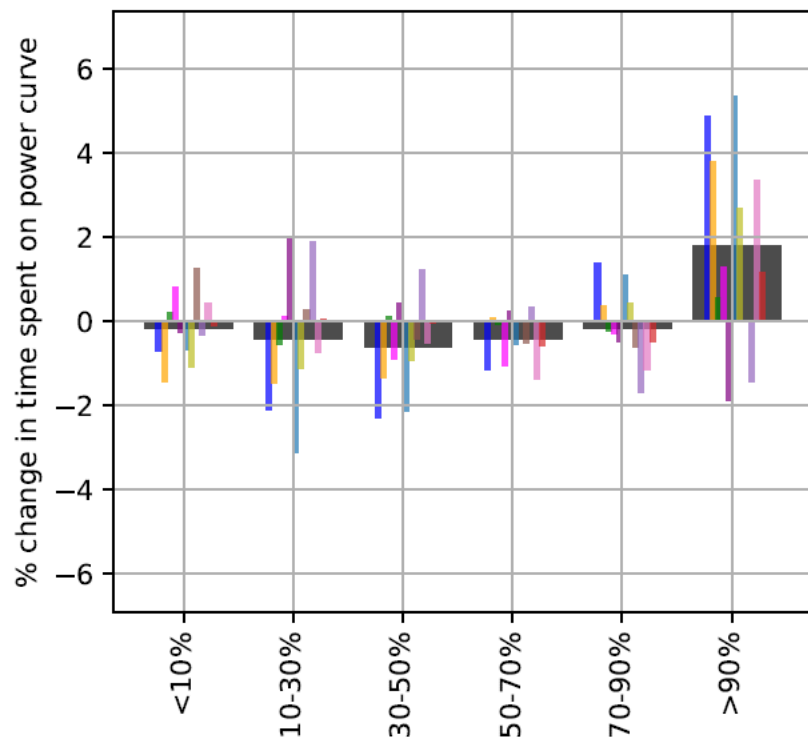
3-Phase Fault at Inchicore (near Dublin)

Mix of droop + dVOC grid-forming controls

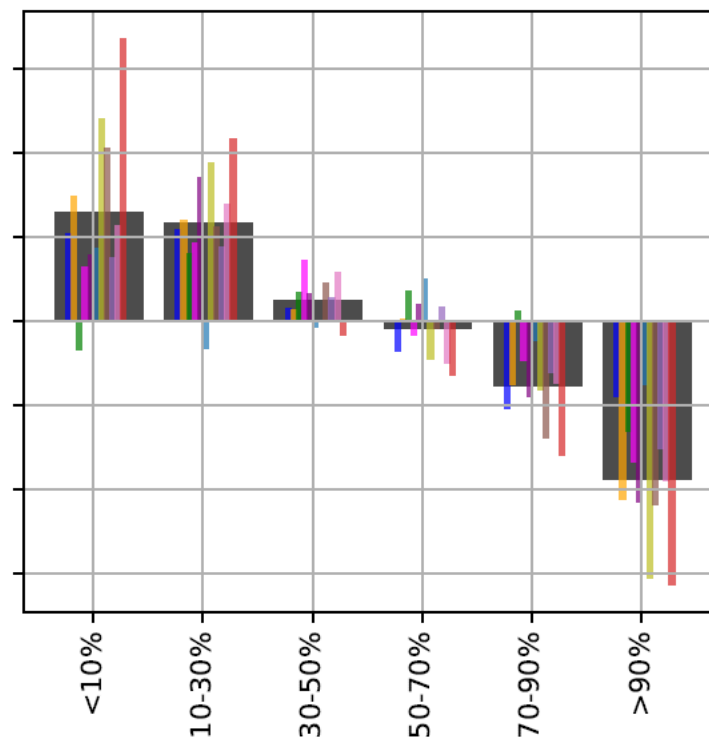


Wind Power Distribution 2081-2100

Winter

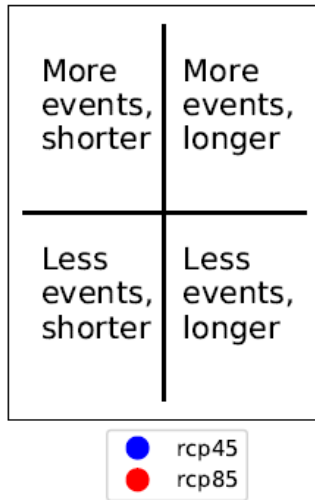


Summer

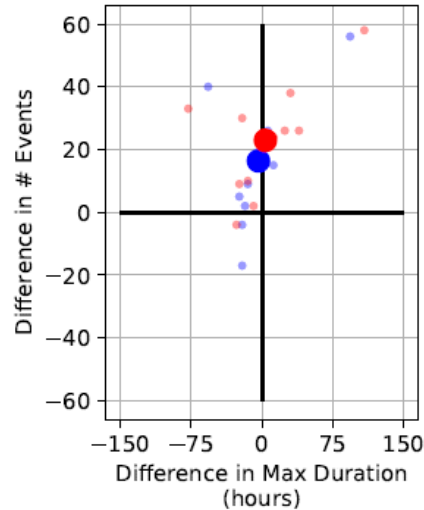


Extended Low-Power Events 2081-2100

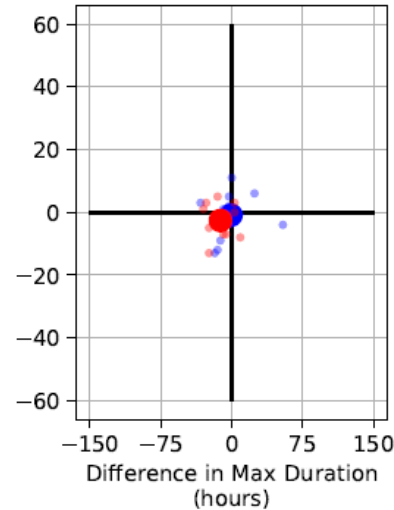
Onshore



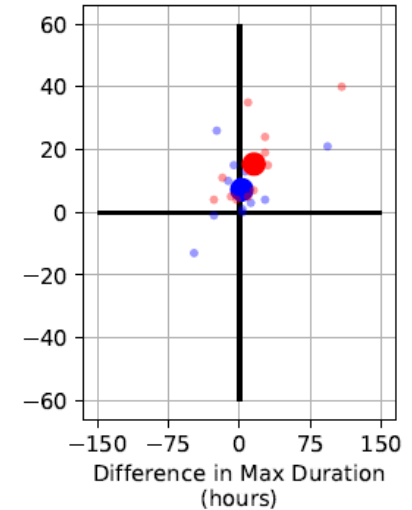
Annual



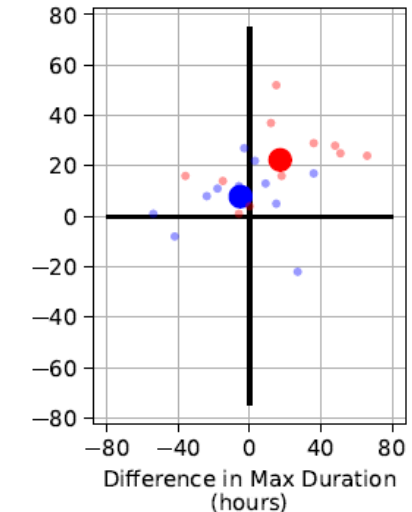
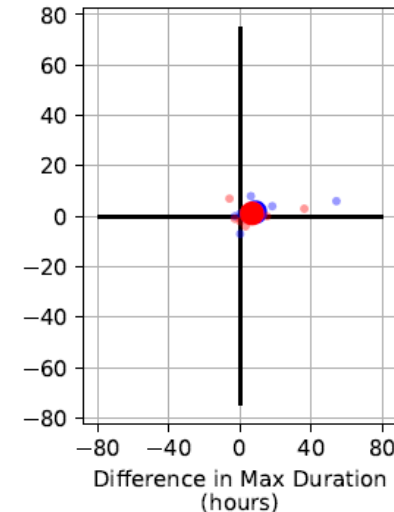
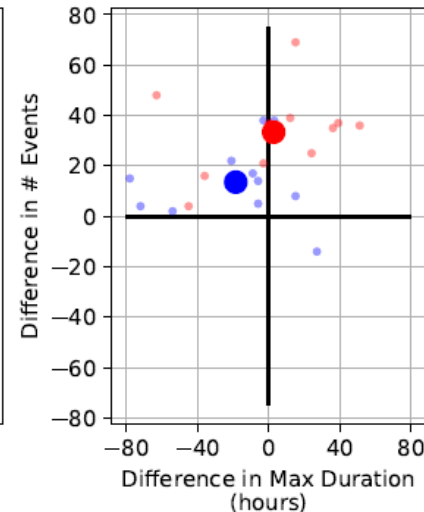
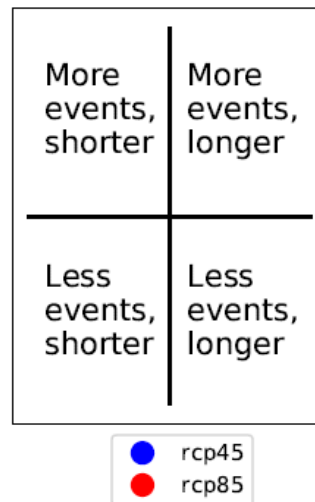
Winter



Summer



Offshore



... 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 CO₂ reduction objectives outweigh economic / least cost motivations?*

Present and Future Operation of the Ireland Power System

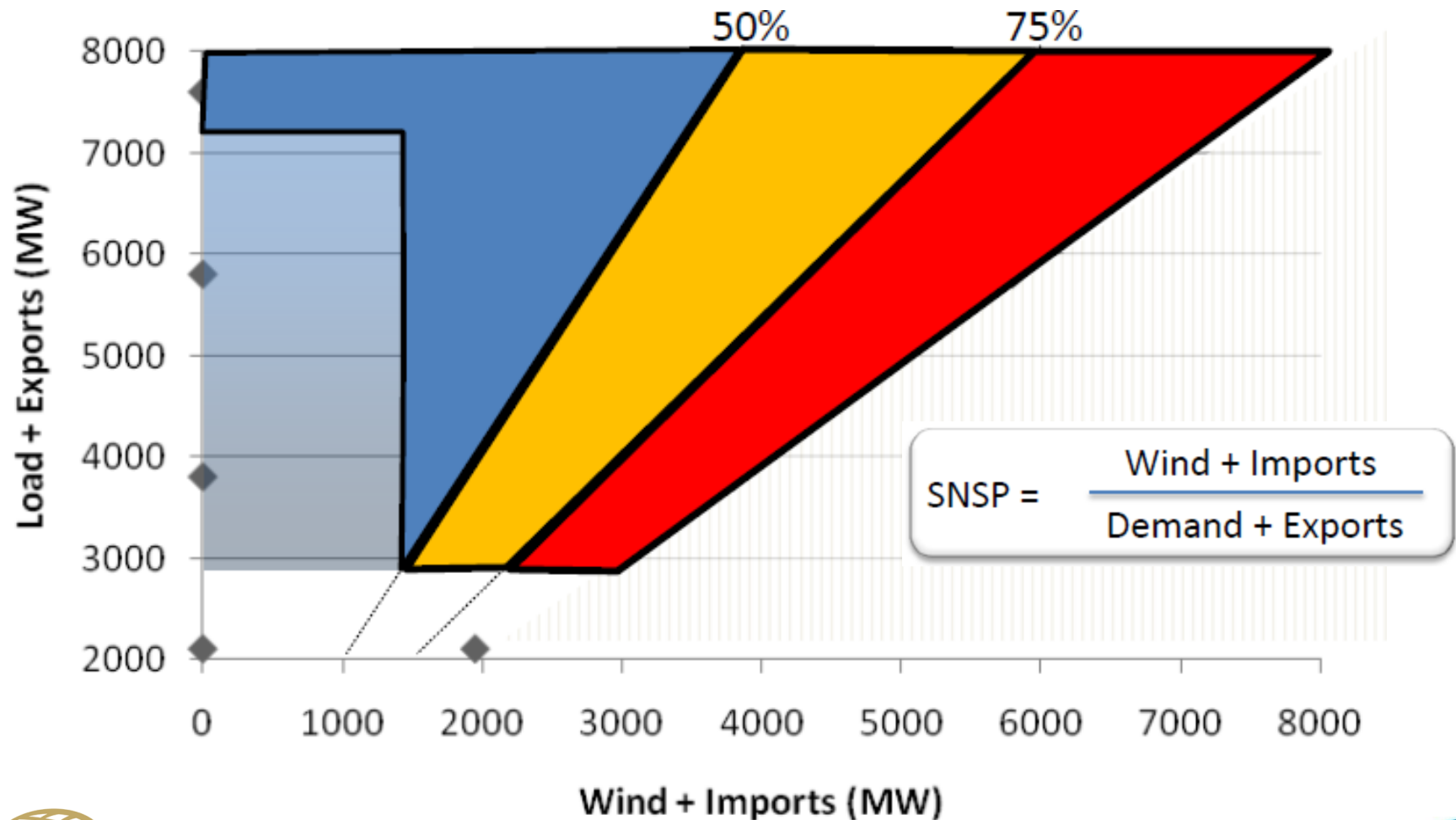
Damian Flynn

(damian.flynn@ucd.ie)

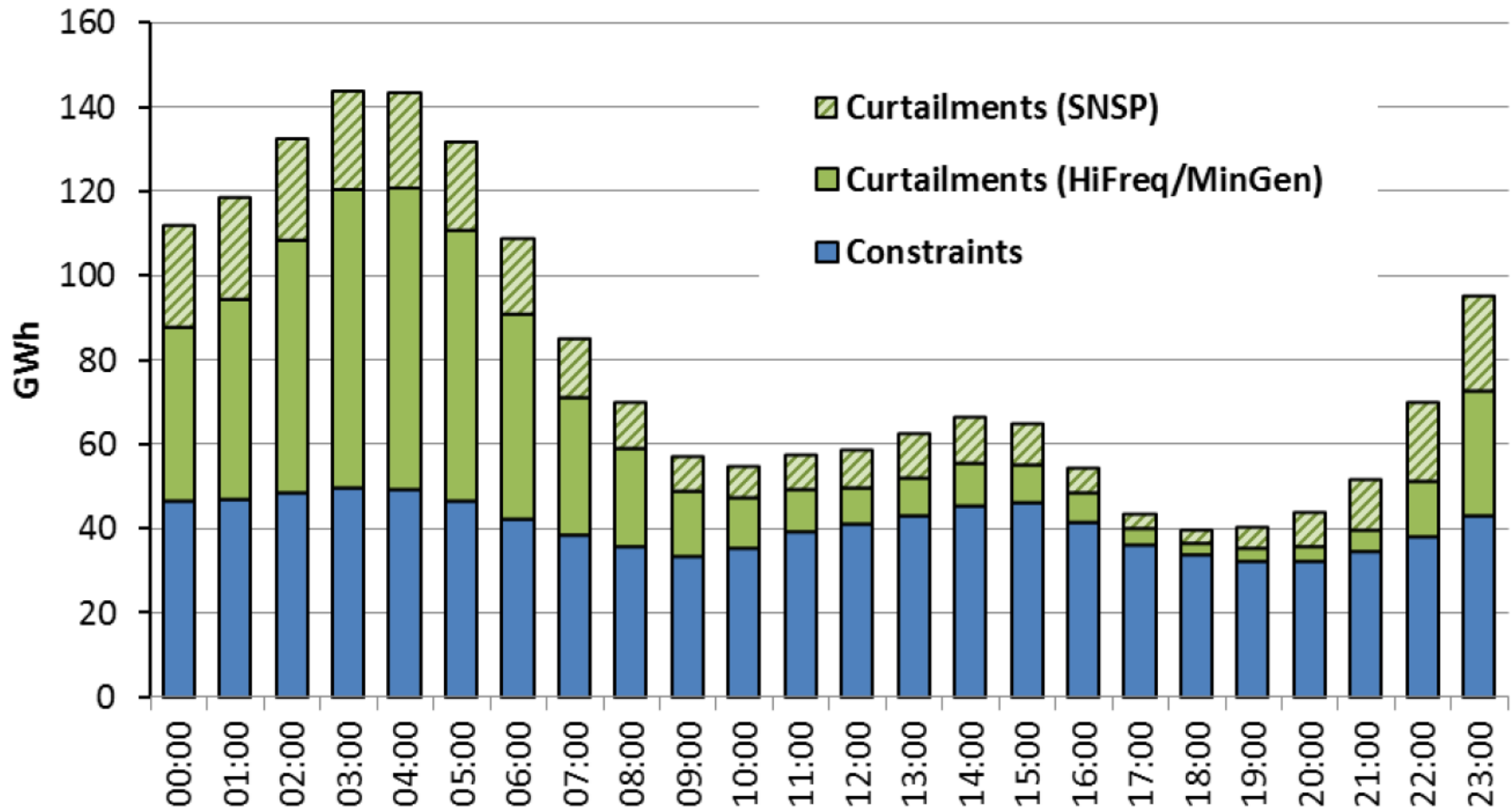
University College Dublin



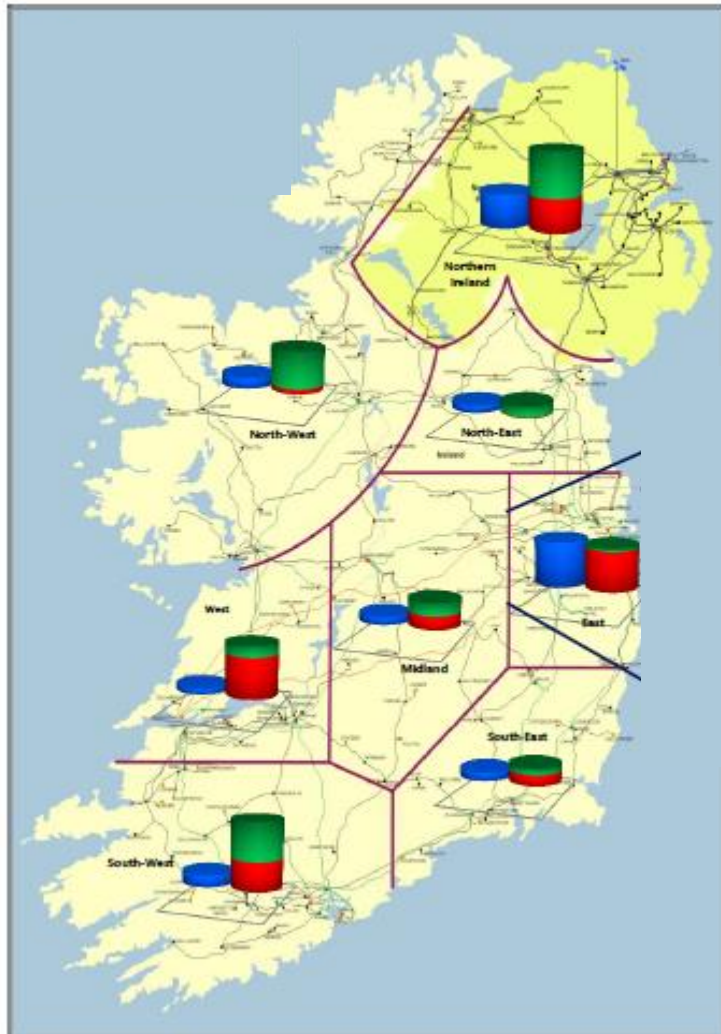
Facilitation of Renewables Studies



Wind Dispatch Down 2020



Load vs. Generation Distribution



Demand

Conventional
Generation

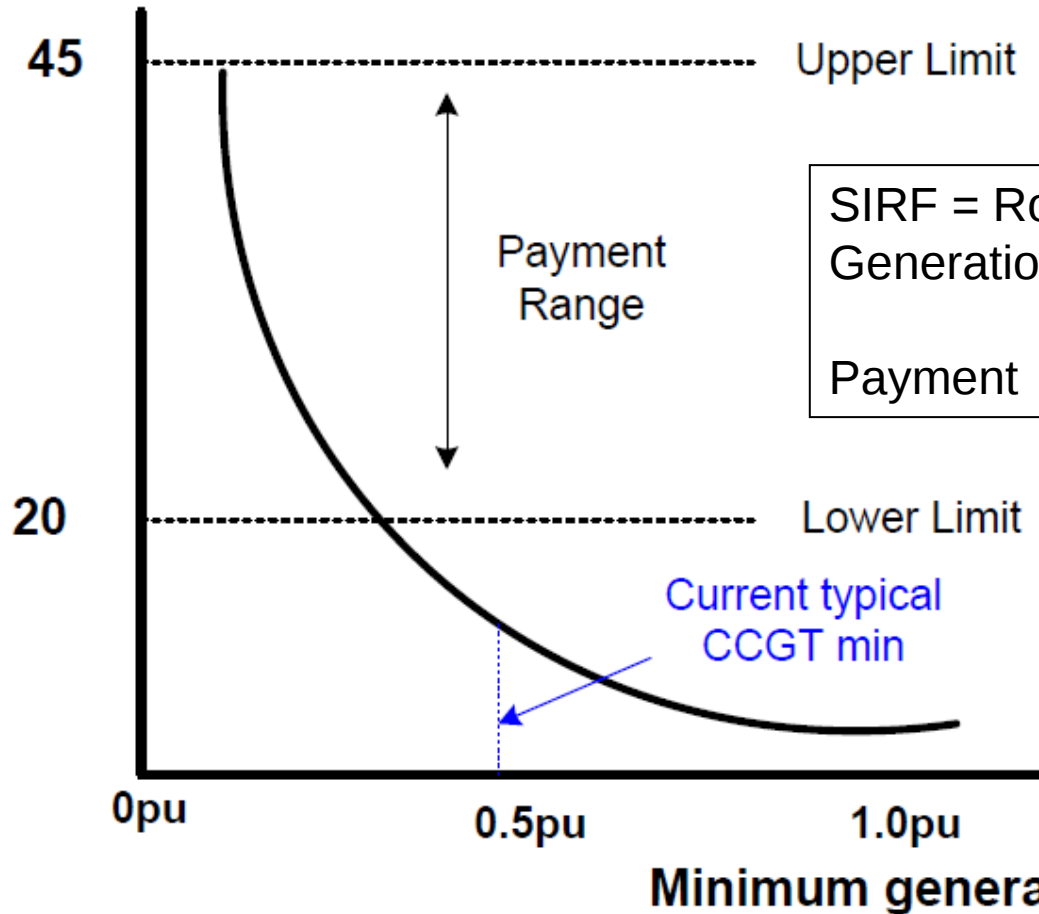
Renewable
Generation



Synchronous Inertial Response



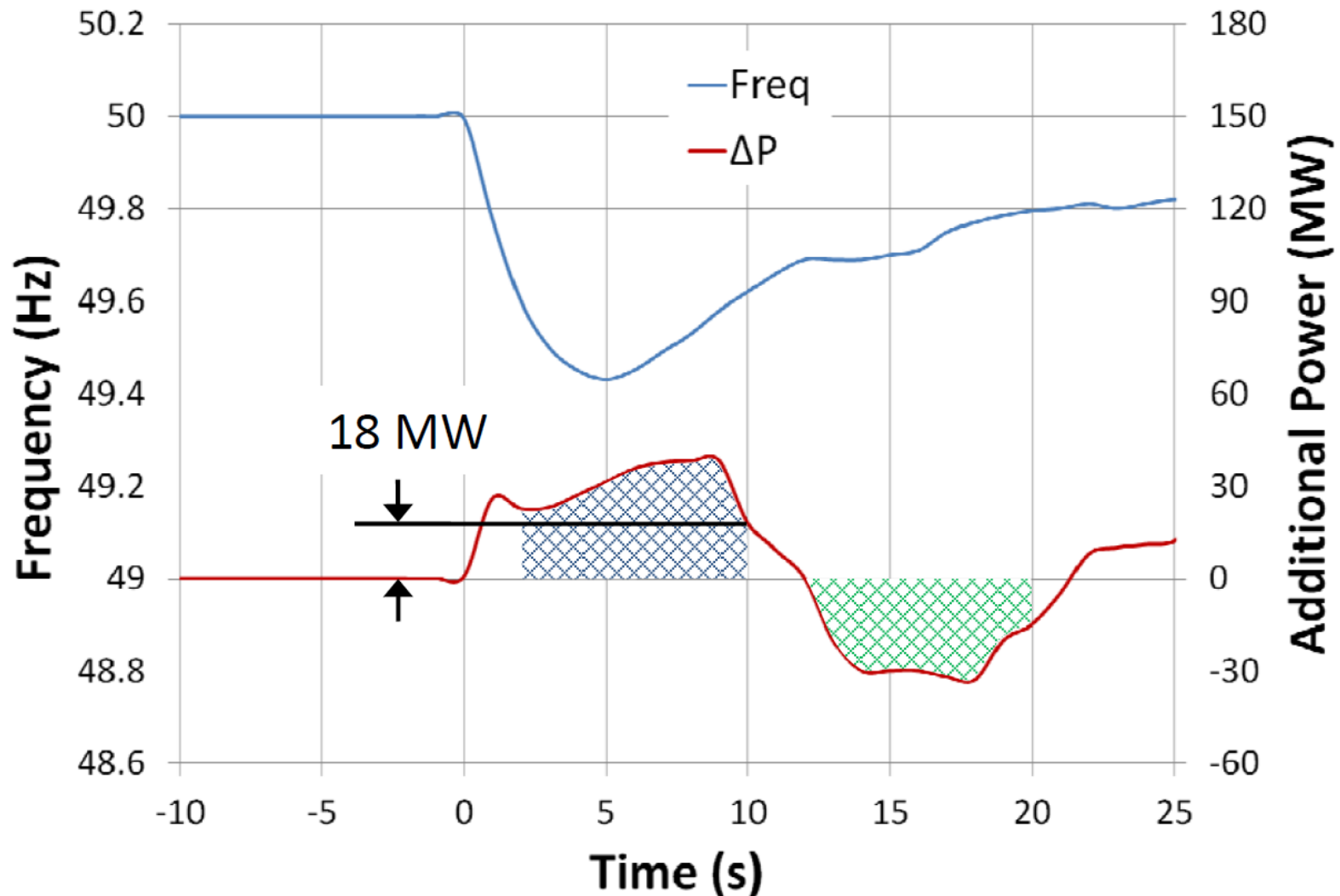
Synchronous Inertial
Response Factor



$SIRF = \text{Rotational Energy} / \text{Min Stable Generation (s)}$

$\text{Payment} \propto (\text{Rotational Energy} \times SIRF)$

Fast Frequency Response



Dynamic Reactive Response

