Megapack

Tesla's Perspective on IBR Overload Capabilities needs of the Grid

ESIG, March 2026

Agenda

- Introduction
- Real power surge needs
- Transmission protection needs
- Current surge needs
- Questions

Megapack 2 XL Overview

① AC Battery Modules (x24)

② Grid-Tied Inverter (x24)

③ Thermal Cabinet Cabinet

④ Customer Interface (AC Breaker)

⑤ Thermal Roof

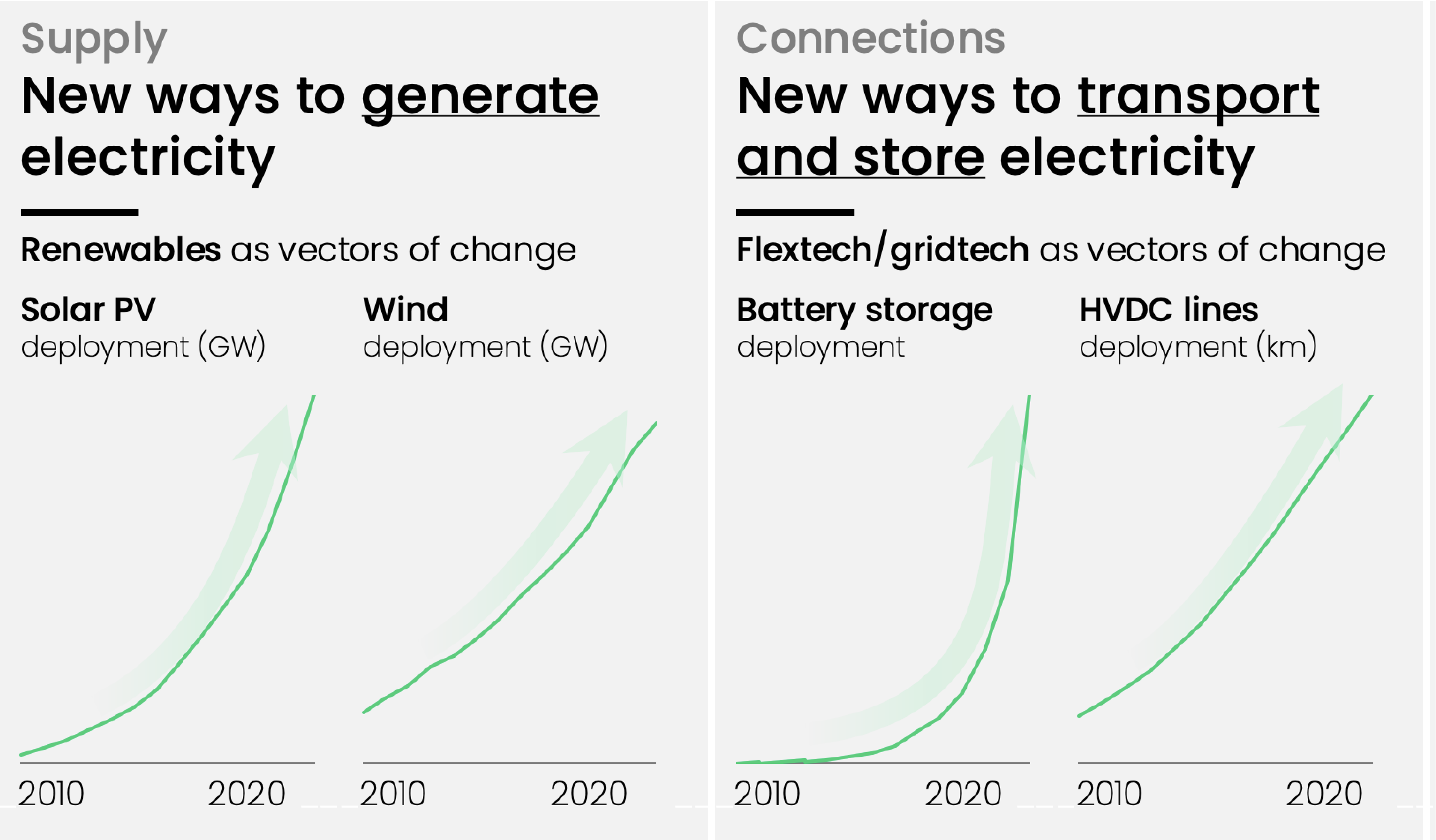
⑥ IP66 Enclosure

2 MW / 4 MWh
Per Unit

∞
Infinitely Scalable

200 MW / 400 MWh
Per Acre

Growth of IBRs on grid



Considerations for overload requirements:

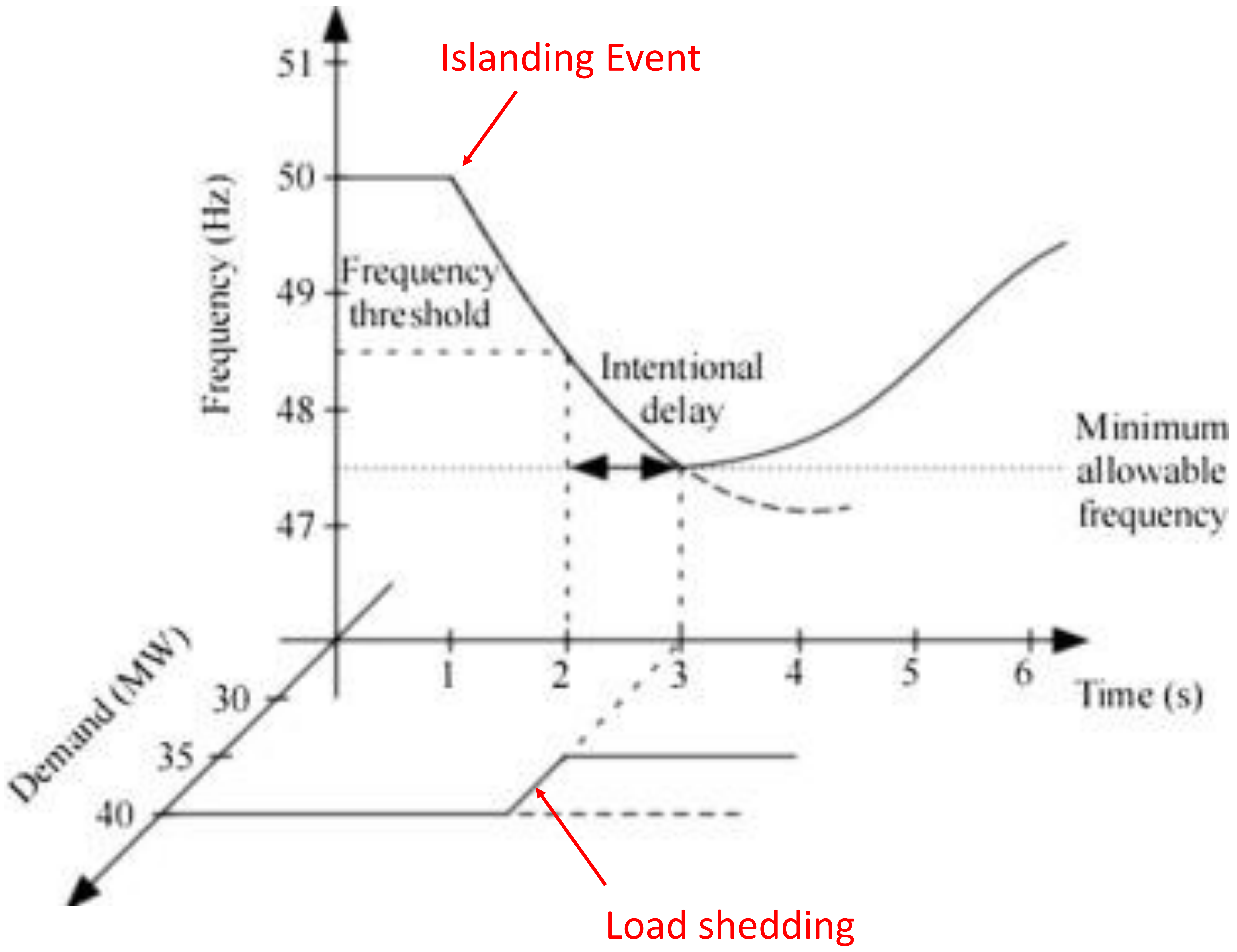
- Get the requirements right first-time
  - Retroactive application will uneconomical
- Think from fundamental needs of the grid and not OEM capabilities
- Over-estimating the needs may result increased cost for everyone (inverters, BOP, transmission protection upgrades, etc)

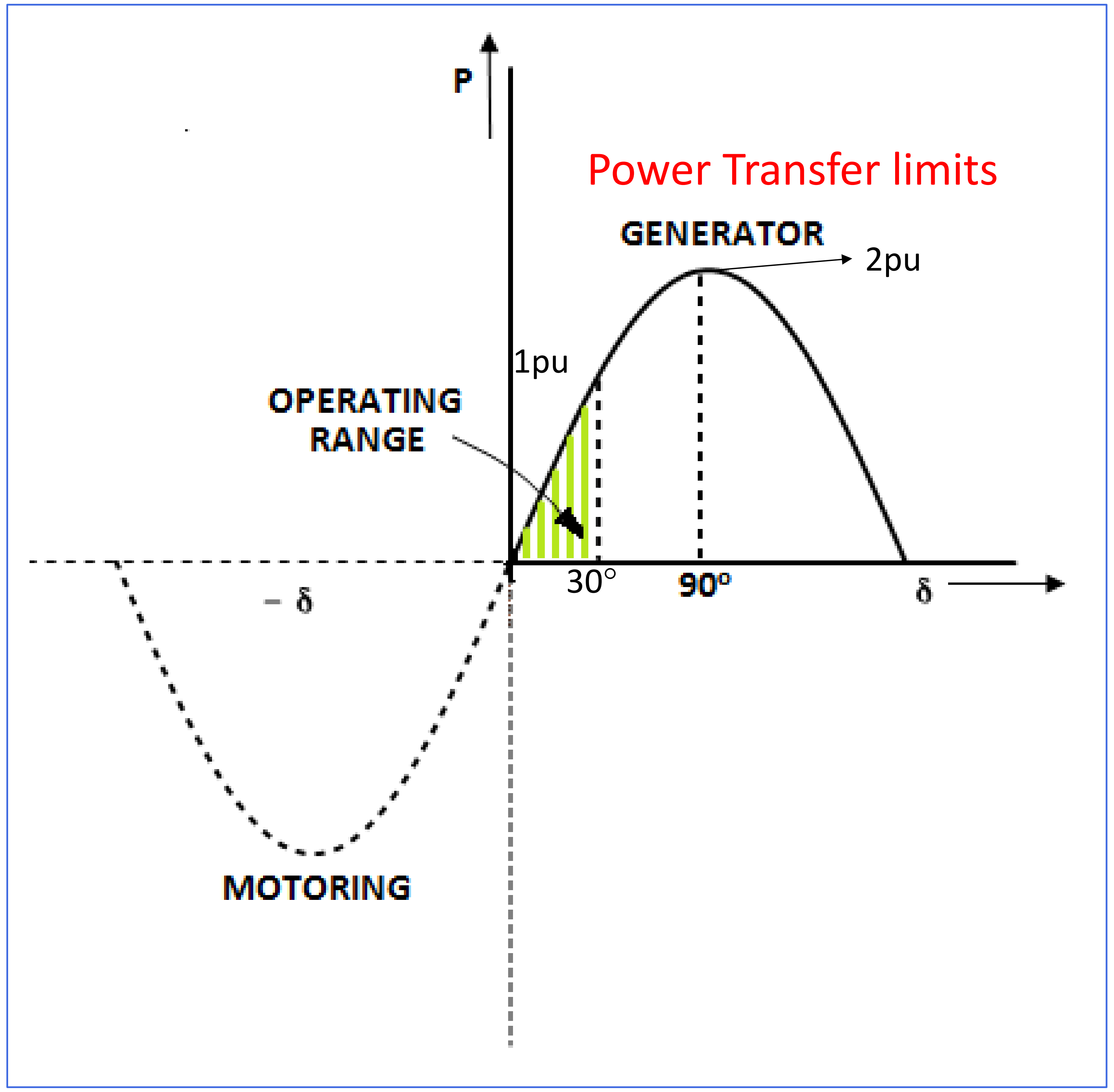
Ref: https://ember-energy.org/app/uploads/2025/09/Slidedeck-The-Electrotech-Revolution-PDF.pdf

IBR real power surge capability needs of the Grid

Real power surge capability

Needed to sustain islanding events in the grid

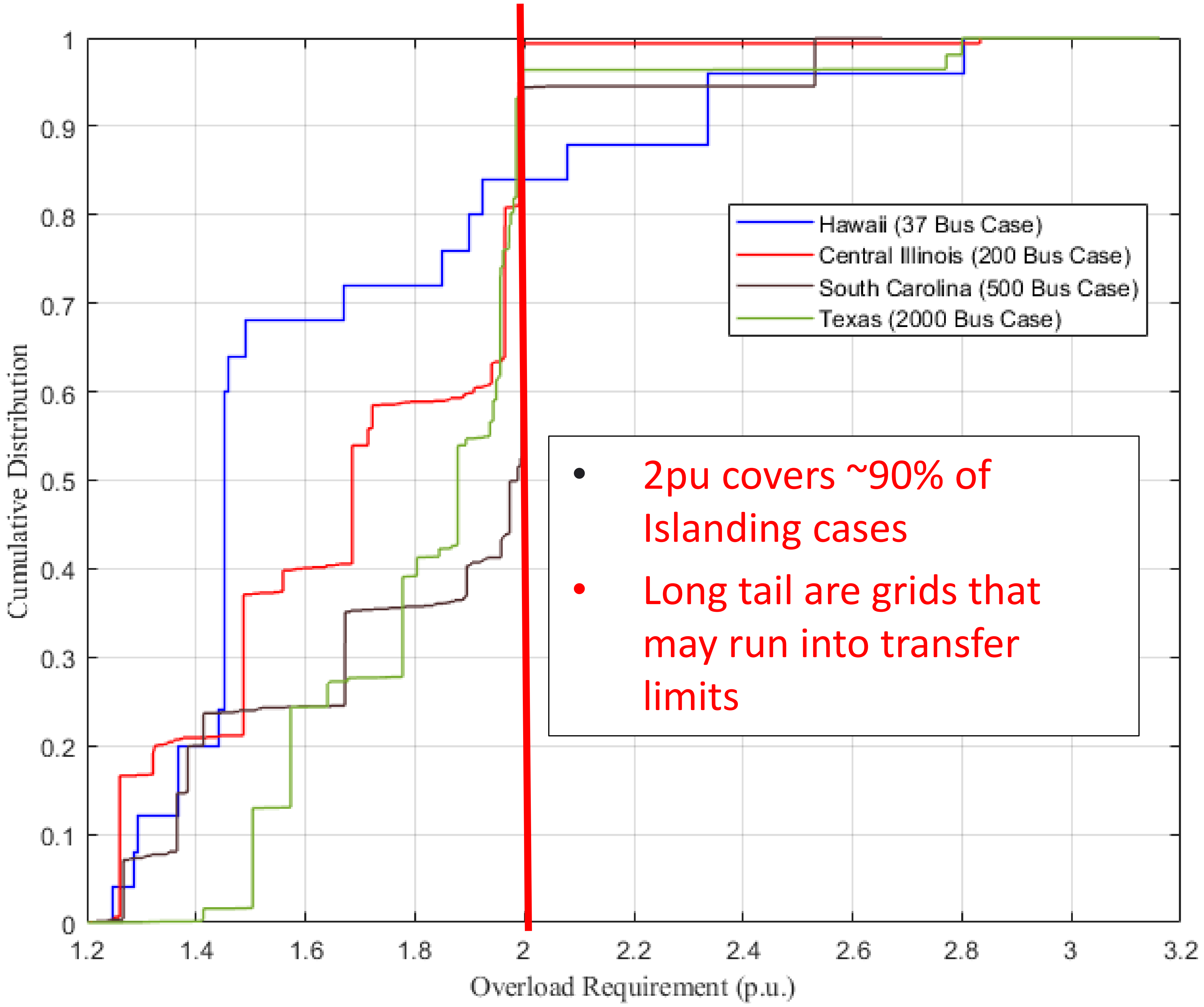




- During an Islanding event, surge power is required to avoid system collapse until balancing actions kicks-in
- Transfer limits: Typical synchronous generators loaded with 30° deg angle to maintain stability => max power transfer of 2pu
  - Given the impedances within IBR's BOP and virtual impedance (GFM controls) similar limitations may apply

Real power surge capability

Needed to sustain islanding events in the grid



Real Power Surge (pu)	Inertia (s)	*ROCOF* (Hz/s)	Time (s) (for 5Hz frequency difference)	Time with margin (s)
2*	5	6	0.83	**1**
1.5	5	3	1.66	**2**
1.25	5	1.25	3.33	**5**
1.1	5	0.6	8.3	**10**

Magnitude

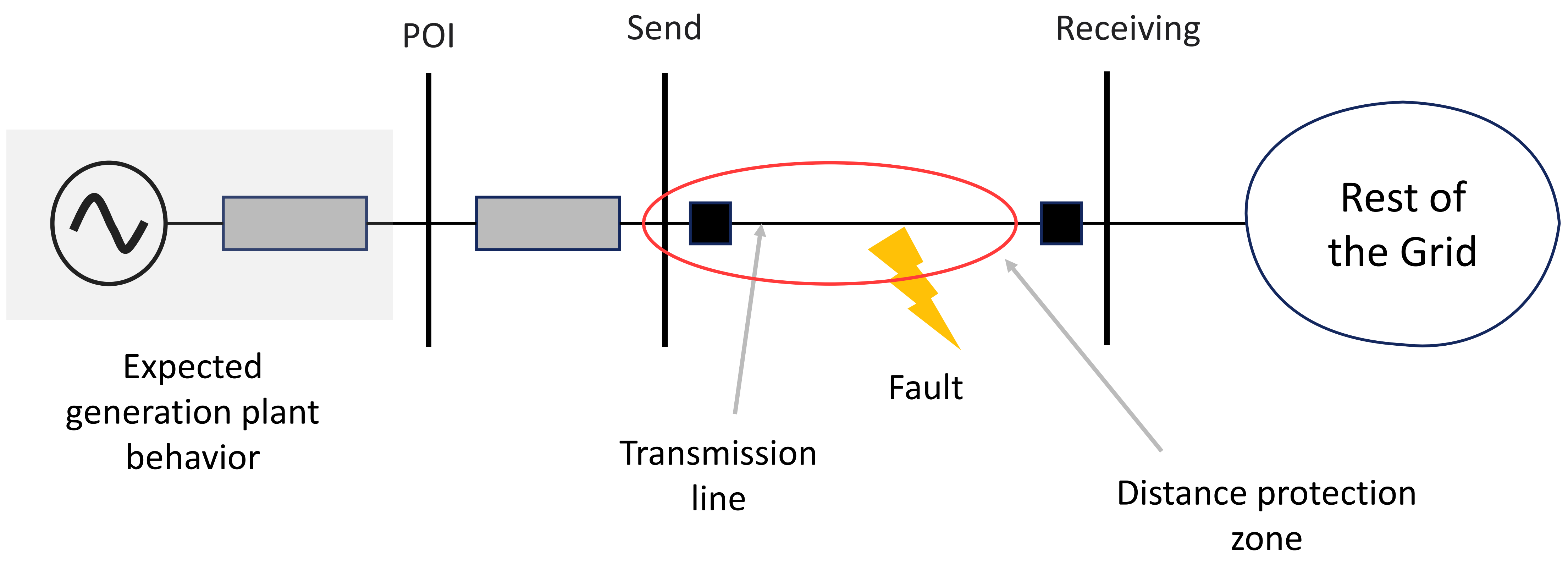
*South Australia 2016 islanding event

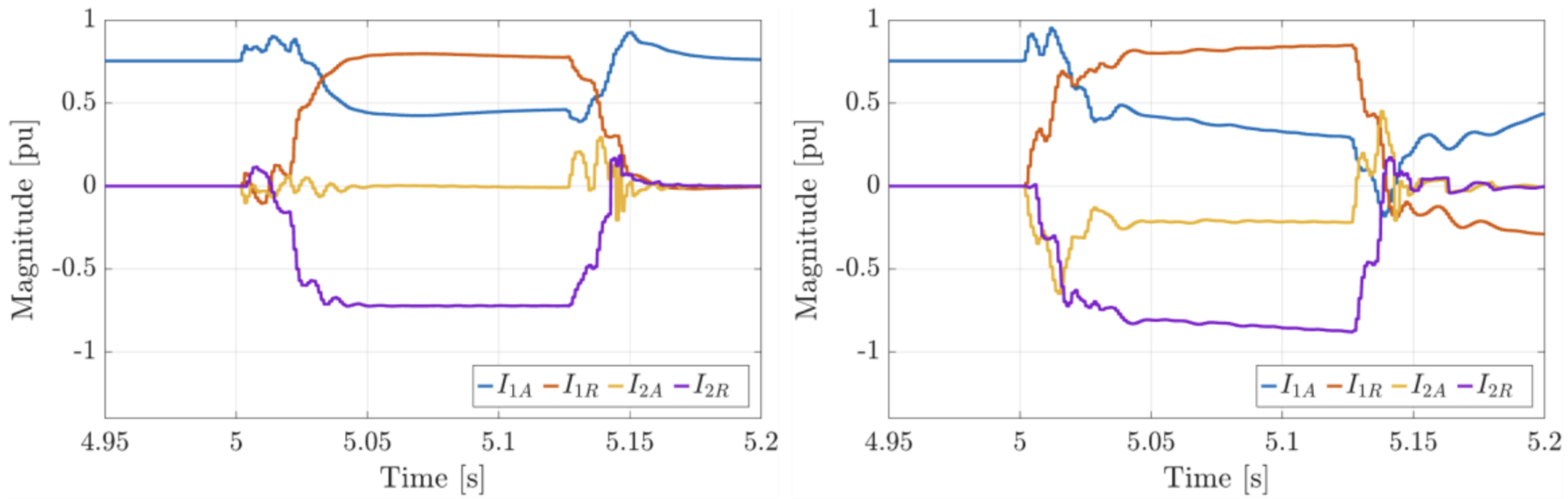
- Overload magnitude is driven by power imbalance in the islands
- Timing for the overload is driven by Inertia (typical value of 5s), and time to achieve 5Hz freq deviation (say 52 Hz to 47 Hz)

IBR current surge capability needs of the Grid

What is needed for Transmission-level Protection

Transmission protection needs voltage source with impedance behavior from Generators; no surge current needed for protection





(a) GFL (b) GFM

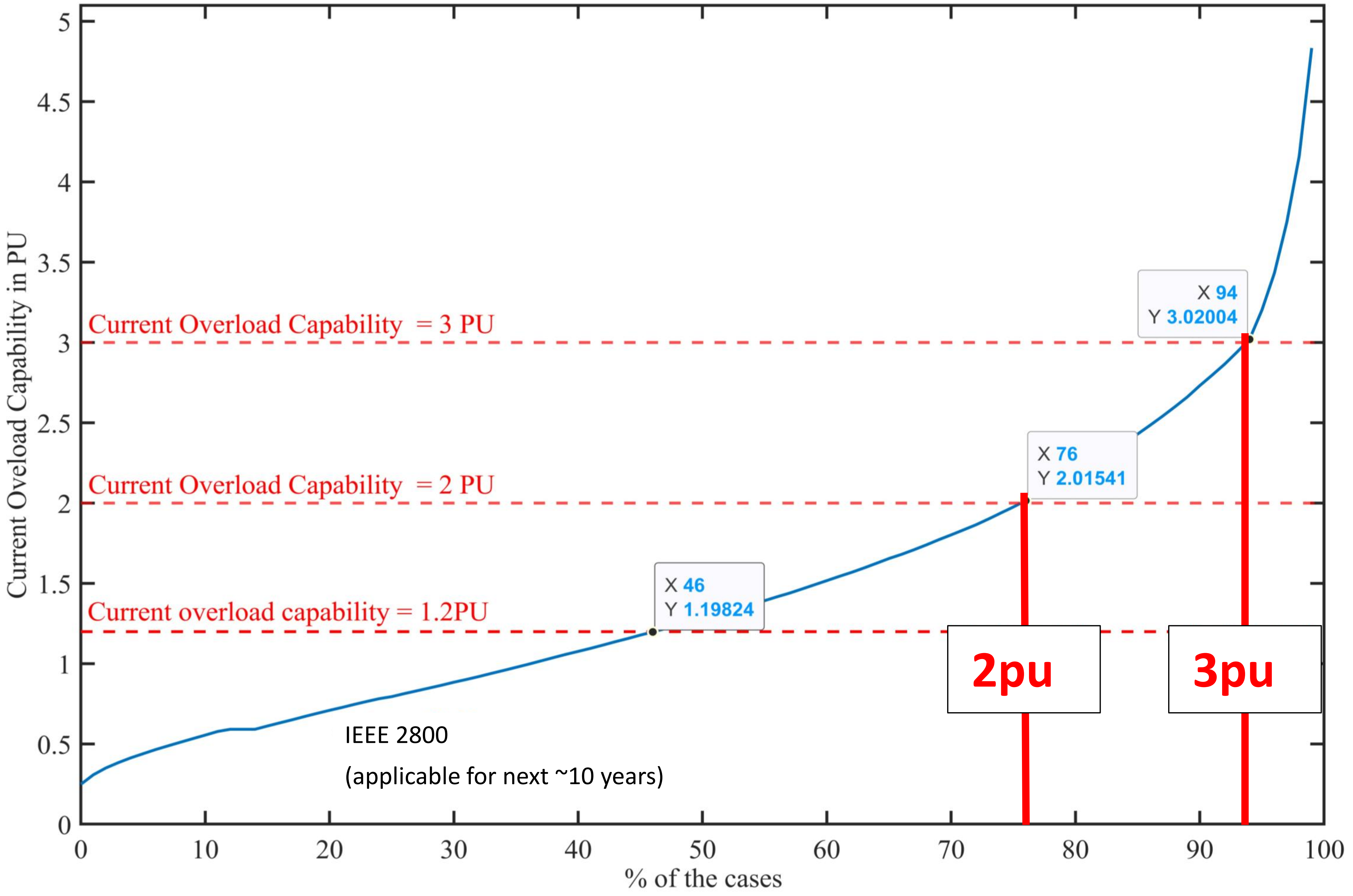
Response to a BC fault [1]

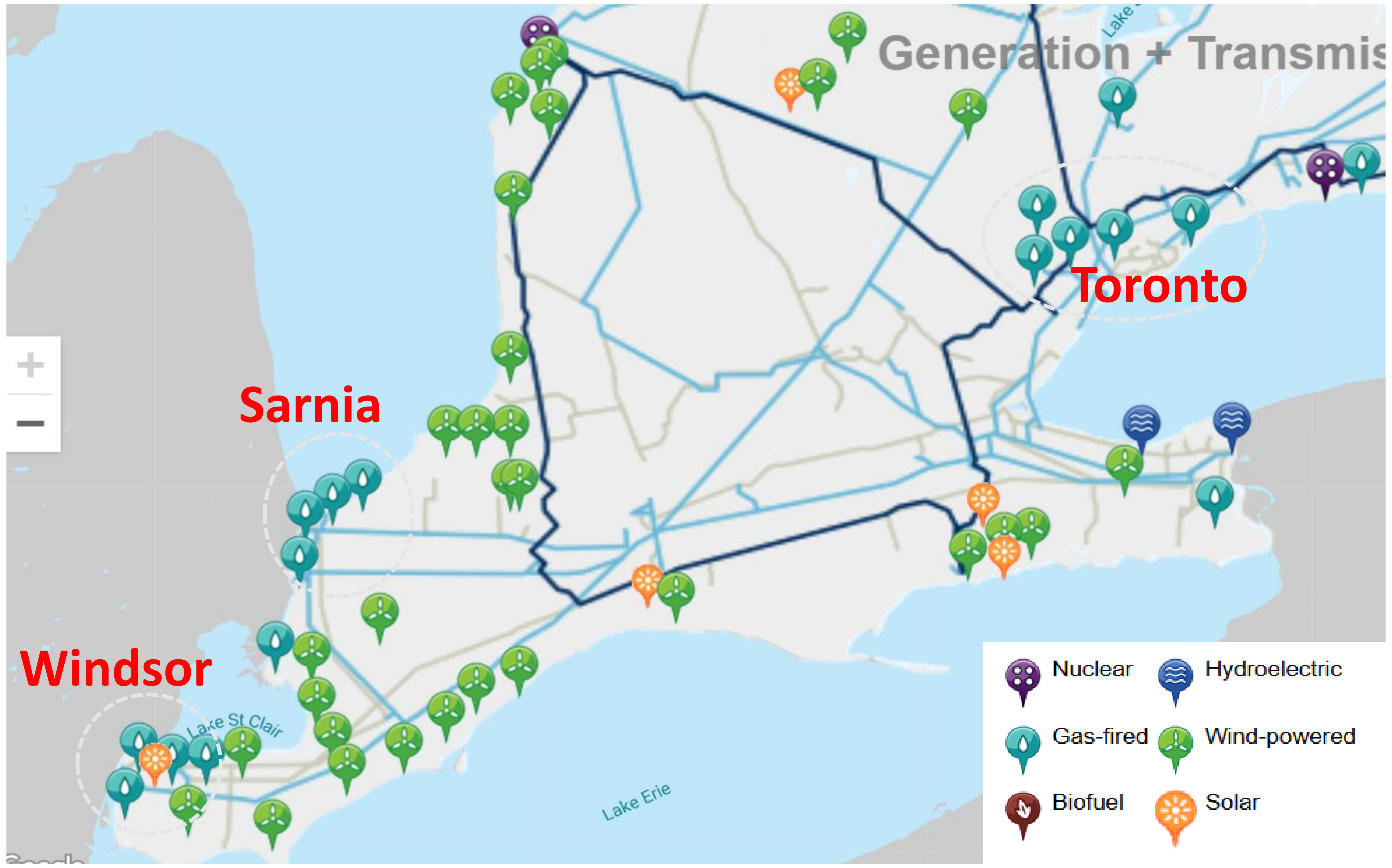
- **Protection** with out any changes to traditional logic can **work with IBRs** [1]
- Current protection expects generators to behaves as balanced voltage source with impedance during faults.
- For IBRs (both GFL and GFM) this translates to:
  - Reactive current injection is enabled
  - Negative sequence injection at appropriate angles
  - Positive and Negative sequence gains must equal (due to fact that positive and negative impedances of generator are approximately equal)
  - When current limits are hit, set the behavior similar to an increased impedance => scaling magnitudes down without affecting the phase angles (not covered in standards)
- No surge current needed for transmission-level protection to function!

Ref: [1] Study of the Protection Improvements for a Weak Grid Area With High Inverter-Based Resources (IBRs). Golden, CO: National Laboratory of the Rockies.

Current surge capability

Needed to sustain voltage at higher levels during faults in regions of high renewable penetrations





- High renewable parts of the network experience lower voltage levels with out surge current capability
  – Potential for those generations to trip if voltage levels fall below ride through requirements
- 2 pu supports surge current needs for 76% of projects within the high renewable areas as of today
  – 3 pu can support 94% of projects within the high renewable areas; diminishing returns beyond 3pu
- With an increasing number of renewable projects built away from Synchronous machines need for IBRs to provide surge current is projected to grow
- Challenge: No monitory benefit available for generator owners
  – Developers asks OEMs to further limit overload current (up to 1 pu) to avoid costly system upgrades upstream (HV breaker)

Questions?