Topic 5: IBR and System Restoration

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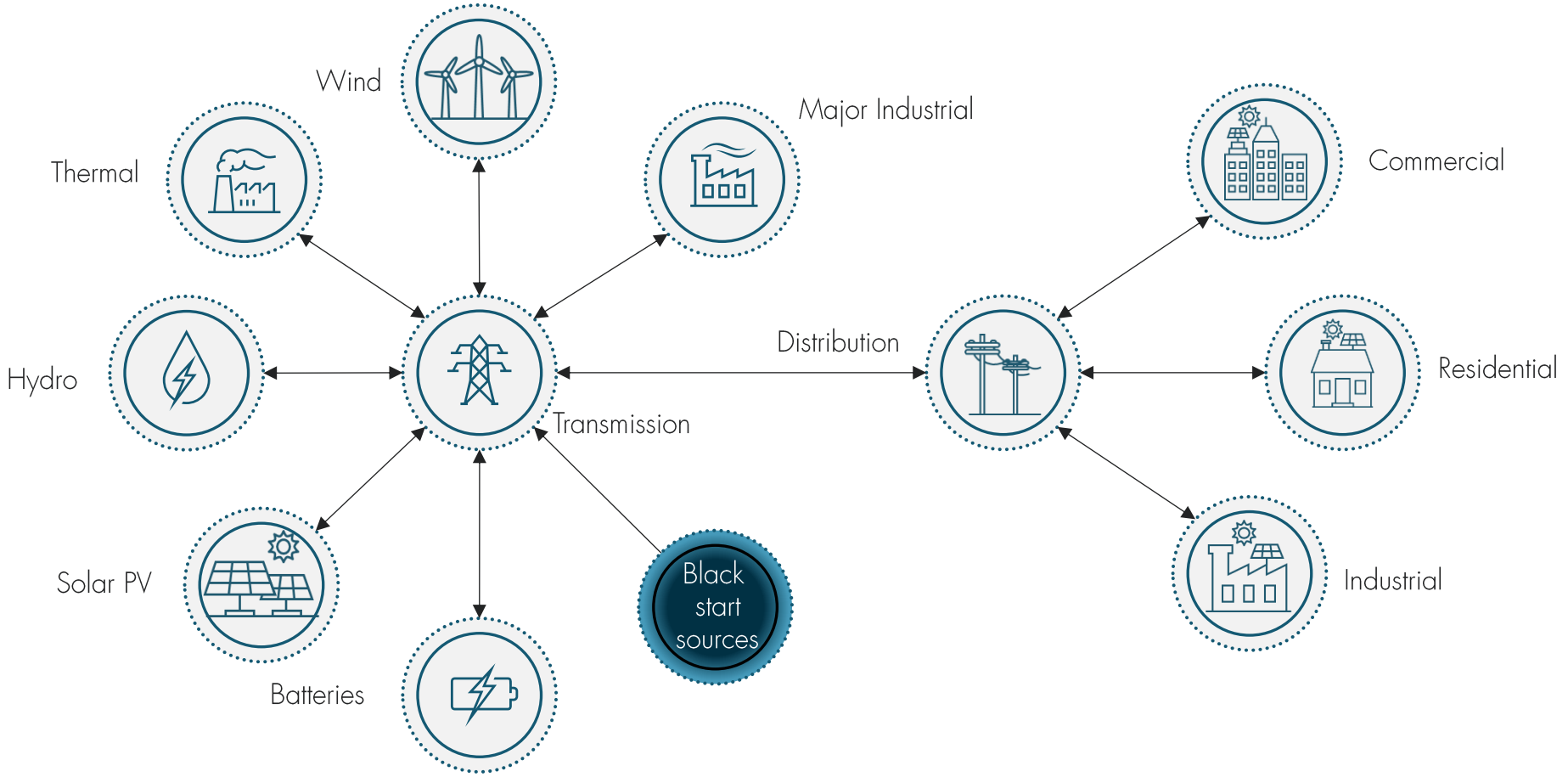
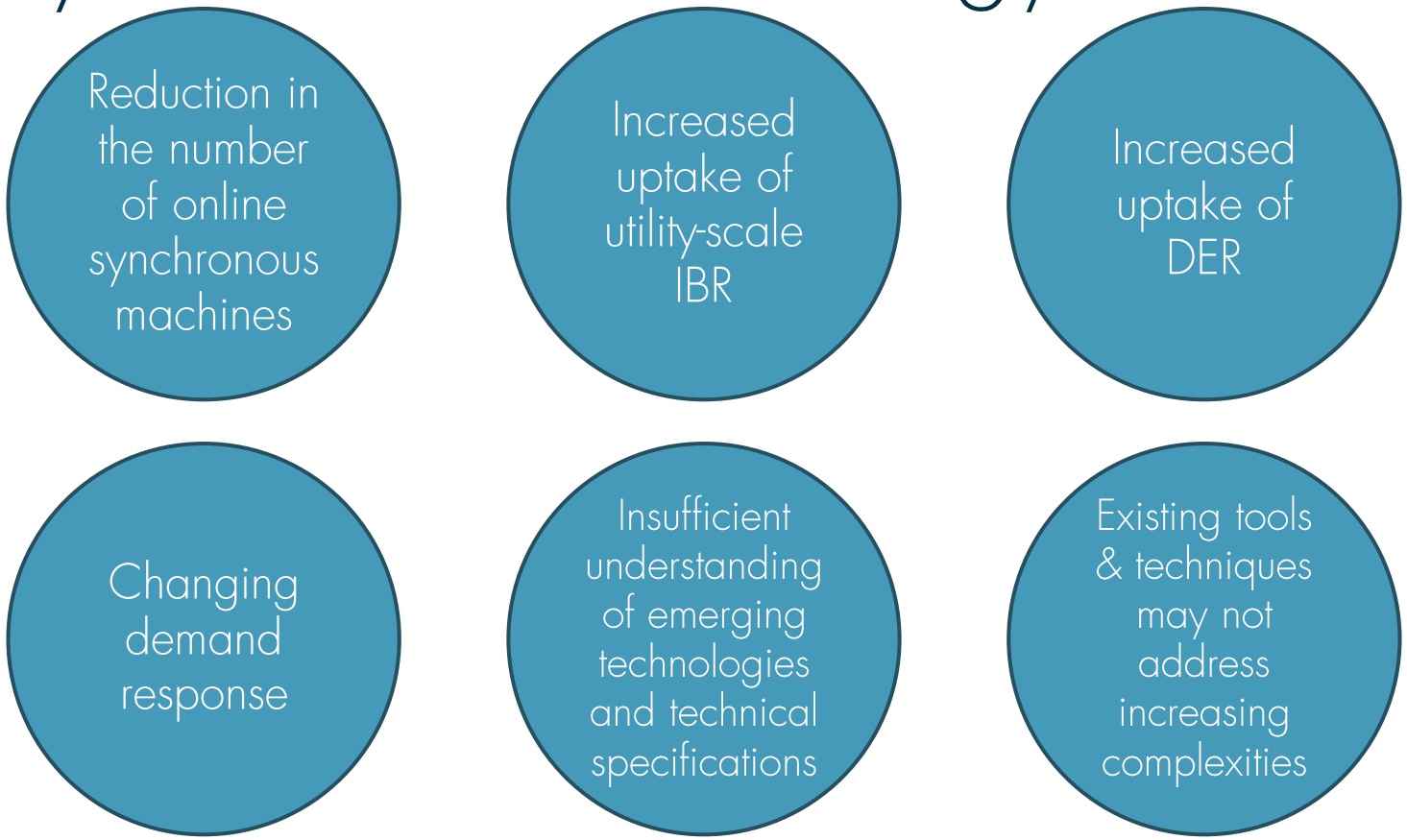
Simplified system restoration process



- Regardless of the fuel source most generators need energy before they can generate energy.
- Non-blackstart synchronous generators are generally energised ahead of IBR.

The importance of considering changing system dynamics due to energy transition



Dynamics associated with system restoration are more complex than those pertaining to system normal, and at the same time less widely investigated.

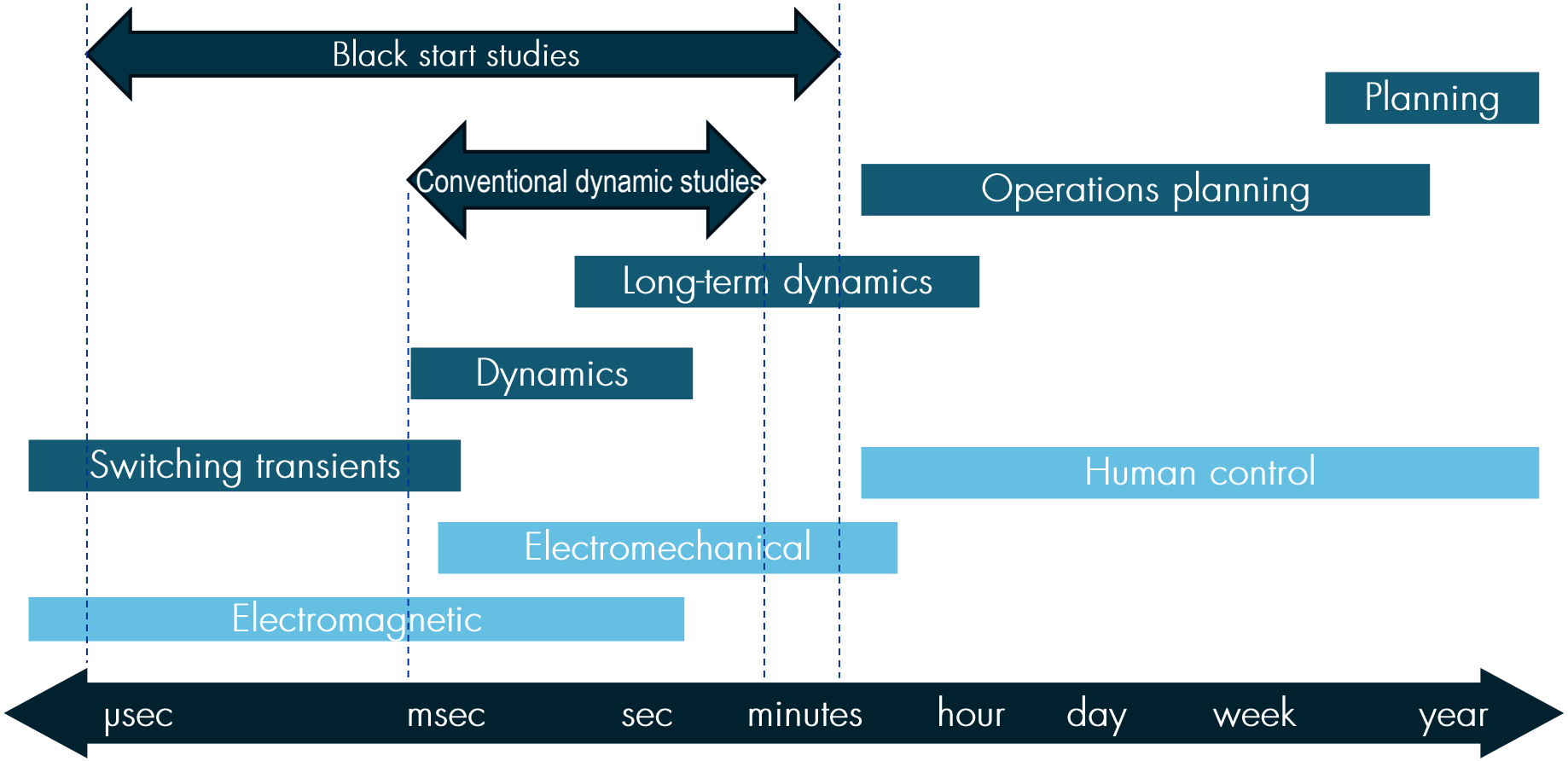
The need for more detailed assessment

Introduction of phenomena not commonly present or irrelevant in a healthy power system

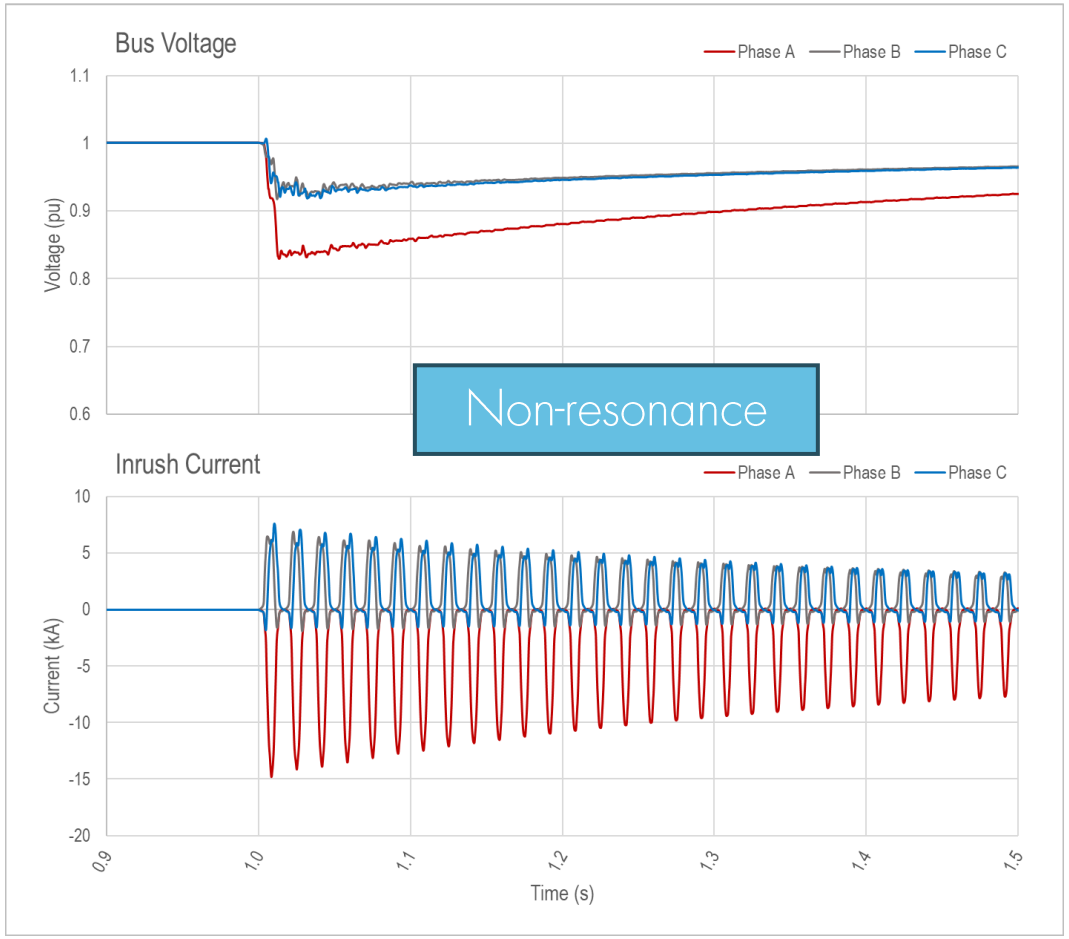
Components operating at extremes of their intended operating design

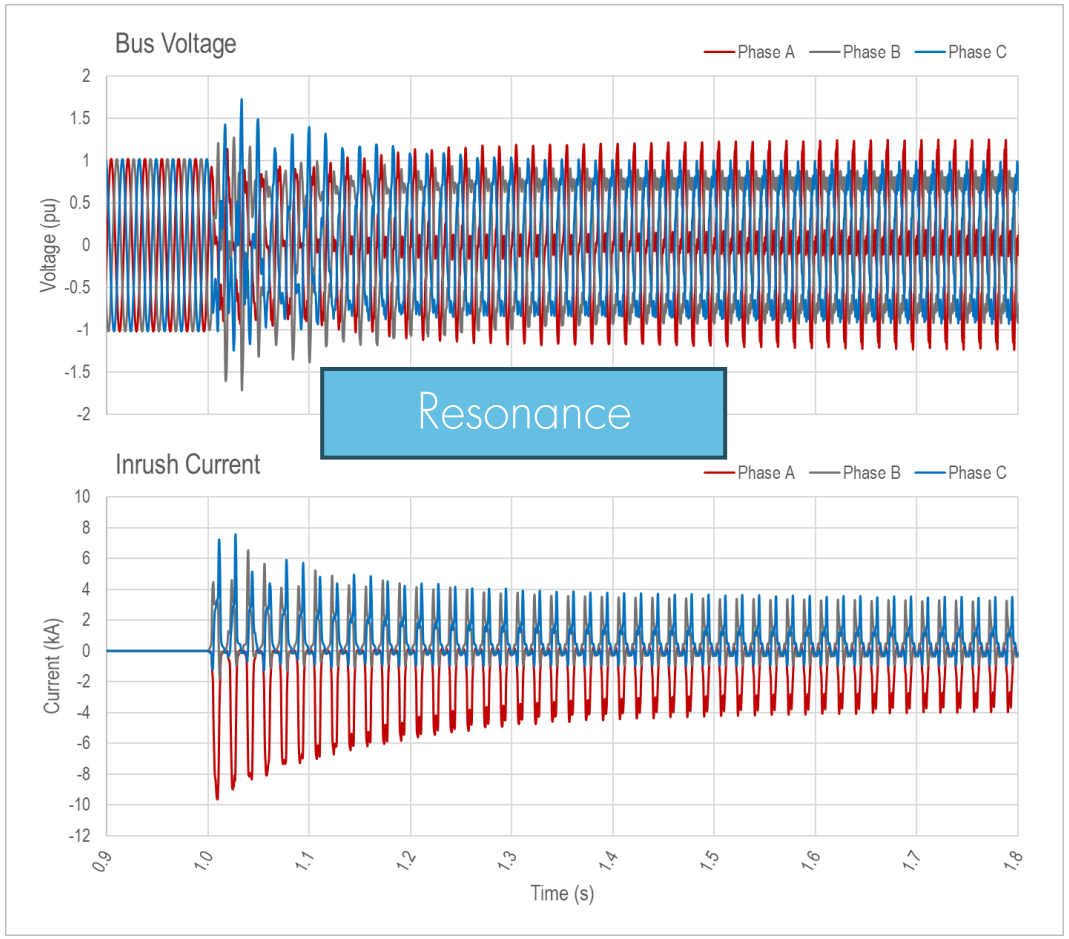
Potential spurious operation of protection systems

Black start vs conventional power system studies



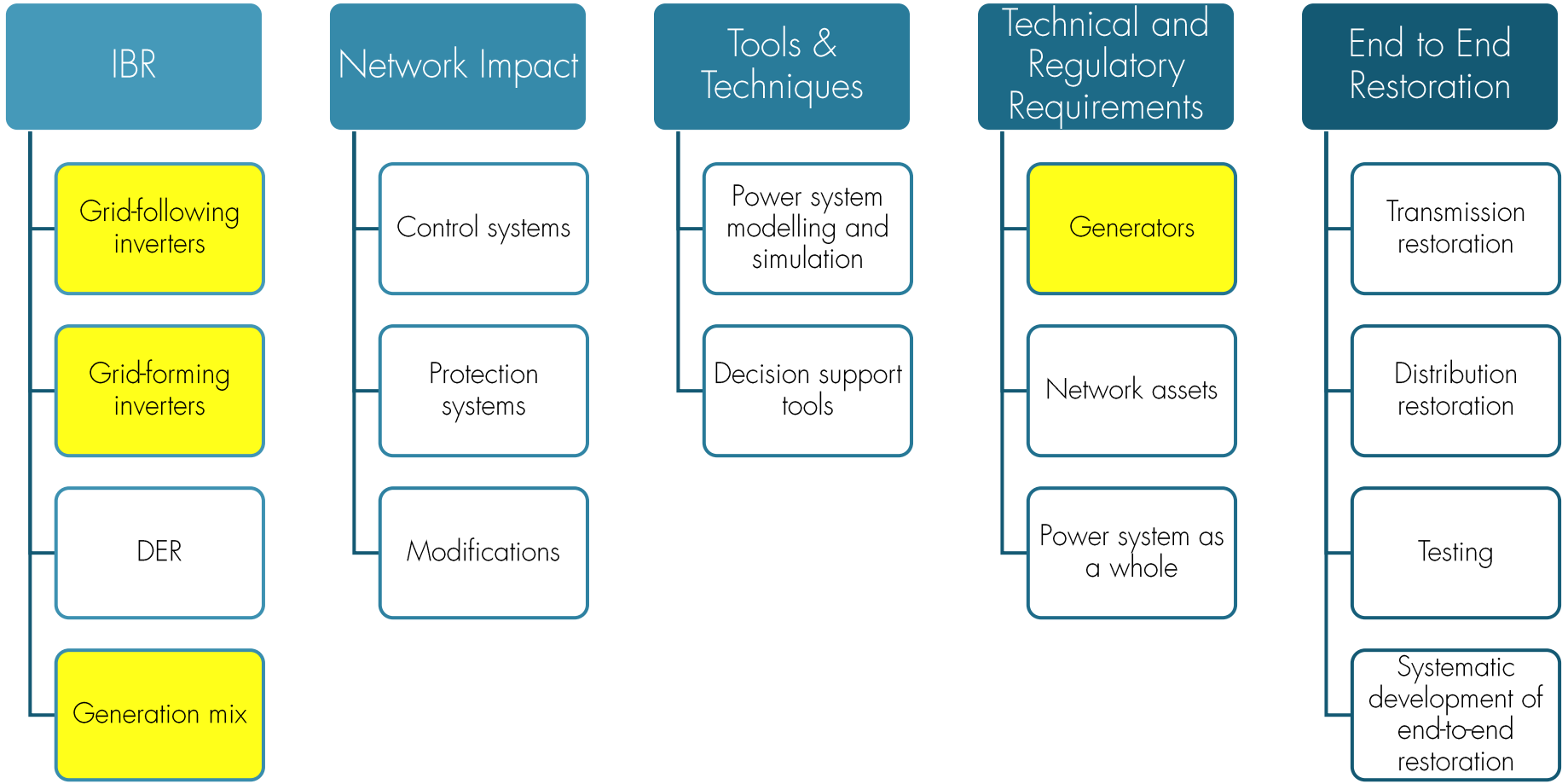
Impact of transformer energisation on network voltages during restart conditions





Source: CIGRE TB 911, Power System Restoration Accounting for Rapidly Changing Power System and Generation Mix, August 2023.

G-PST Topic 5


IBR
Grid-following inverters
Grid-forming inverters
DER
Generation mix
Network Impact
Control systems
Protection systems
Modifications
Tools & Techniques
Power system modelling and simulation
Decision support tools
Technical and Regulatory Requirements
Generators
Network assets
Power system as a whole
End to End Restoration
Transmission restoration
Distribution restoration
Testing
Systematic development of end-to-end restoration

Salient points of previous works (1)

Synchronous generator

- Inherent inertia and damping
- Higher fault current capability
- Requires a minimum stable load

Grid Forming (GFM) Batteries

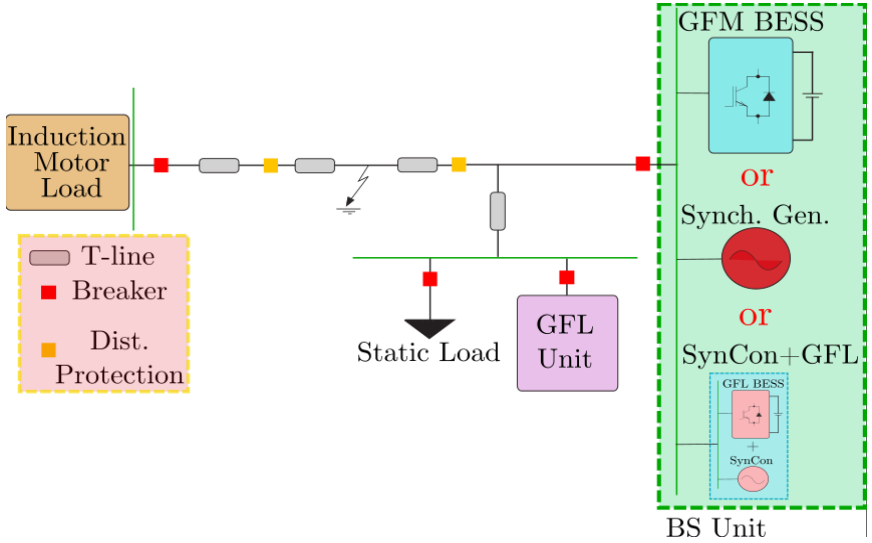
- Emulates most capabilities of a black start synchronous generator
- Faster speed of response
- Comparable or better performance

Synchronous condenser + Grid Following (GFL) Batteries

- Synchronous condenser to form the voltage
- GFL BESS to control the frequency
- Lower capability than the other two options

- Multi-machine Thevenin source model with vendor-specific models of GFL and GFM inverters.
- Much easier to relate responses to particular plant and particular controls within the plant.

Vendor-specific EMT modelling



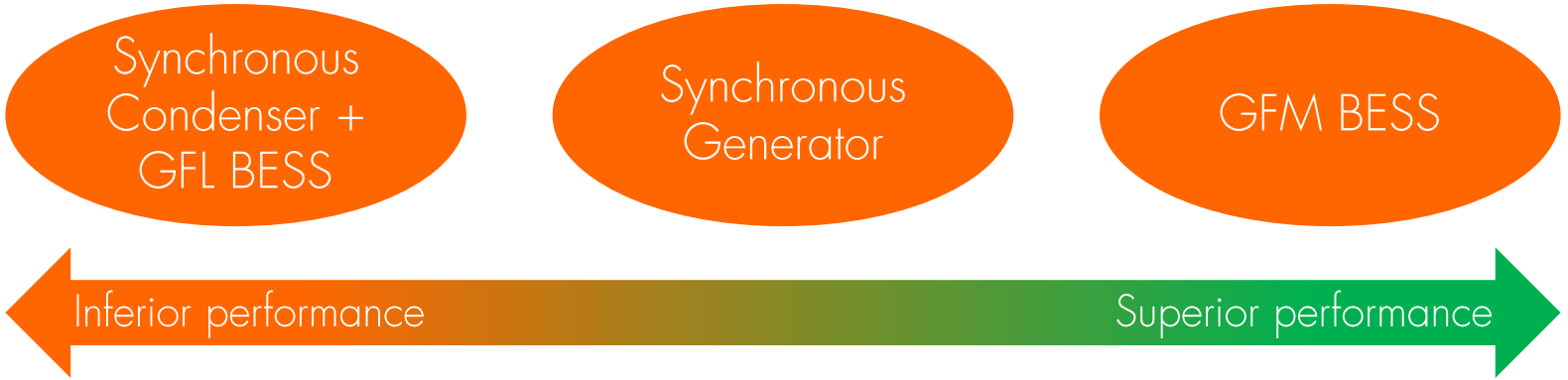
Salient points of previous works (2)

Critical failure mechanisms

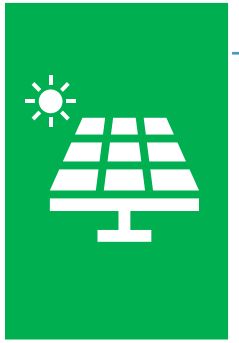
- Plant disconnection due to protection operation
- Excessive temporary over-voltages
- Excessive harmonic voltage distortion
- Frequency collapse
- Sustained low-frequency oscillations

Additional learnings

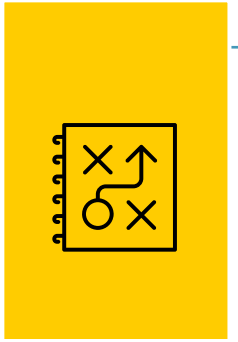
- Synchronous condenser with GFL inverter requires further work
- Synchronous generator loading level has no material impact



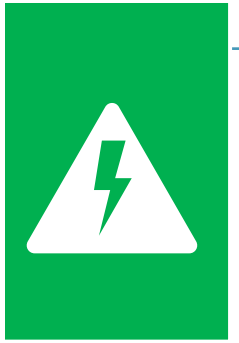
2024 Investigation areas



Impact of distributed energy resources behaviour during 100% IBR system restart



Operational changes to enhance stability during 100% IBR system restart



Impact of network protection during 100% IBR system restart

Development of a high-level procurement timeline tool

Transferability of findings

- System restart can result in system stability, power quality and protection-related phenomena.

- All these can be experienced from one system to another despite topological and technology differences.
  - For example, the application of grid-forming inverters in large-scale system restoration has been recently demonstrated in a couple of other countries.

- Key transferable findings for the 2024 research includes:
  - The role of network components other than large-scale generation including DER and protection systems
  - Identification of new forms of restoration failure, in particular those associated with control interactions and protection failure, and how they can be potentially overcome.


Thank you