Grid Integration of Renewables

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Presentation Outline

- Problem and Technical Impact
- Energy Storage Systems
- Other Technical Challenges
- Resilience
- Conclusions

Problem and Technical Impact

Sources of Concern

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- RE is non-dispatchable
  - Excess energy from RE may be wasted
  - Storage needed to match generation and load.
- VRE generators employ power electronic converters.
  - Behavioural response to disturbances very different from conventional generation.
  - Influence grid stability.

VRE generators have different attributes to conventional generators. Is different (un)desirable?

Grid Codes

- Required by every power system. (Connection, operating, planning and market).
- Technical specifications that **must be satisfied** for any facility to connect to the power system.
- Guide the evolution of the developing needs of the power system.
- Regularly revised.
- In Caribbean islands usually the responsibility of public sector.

VRE generators have to accept more responsibilities as they replace conventional generators. Grid codes can serve to ensure this successful transition.

RE Technical Impact on Grid Codes

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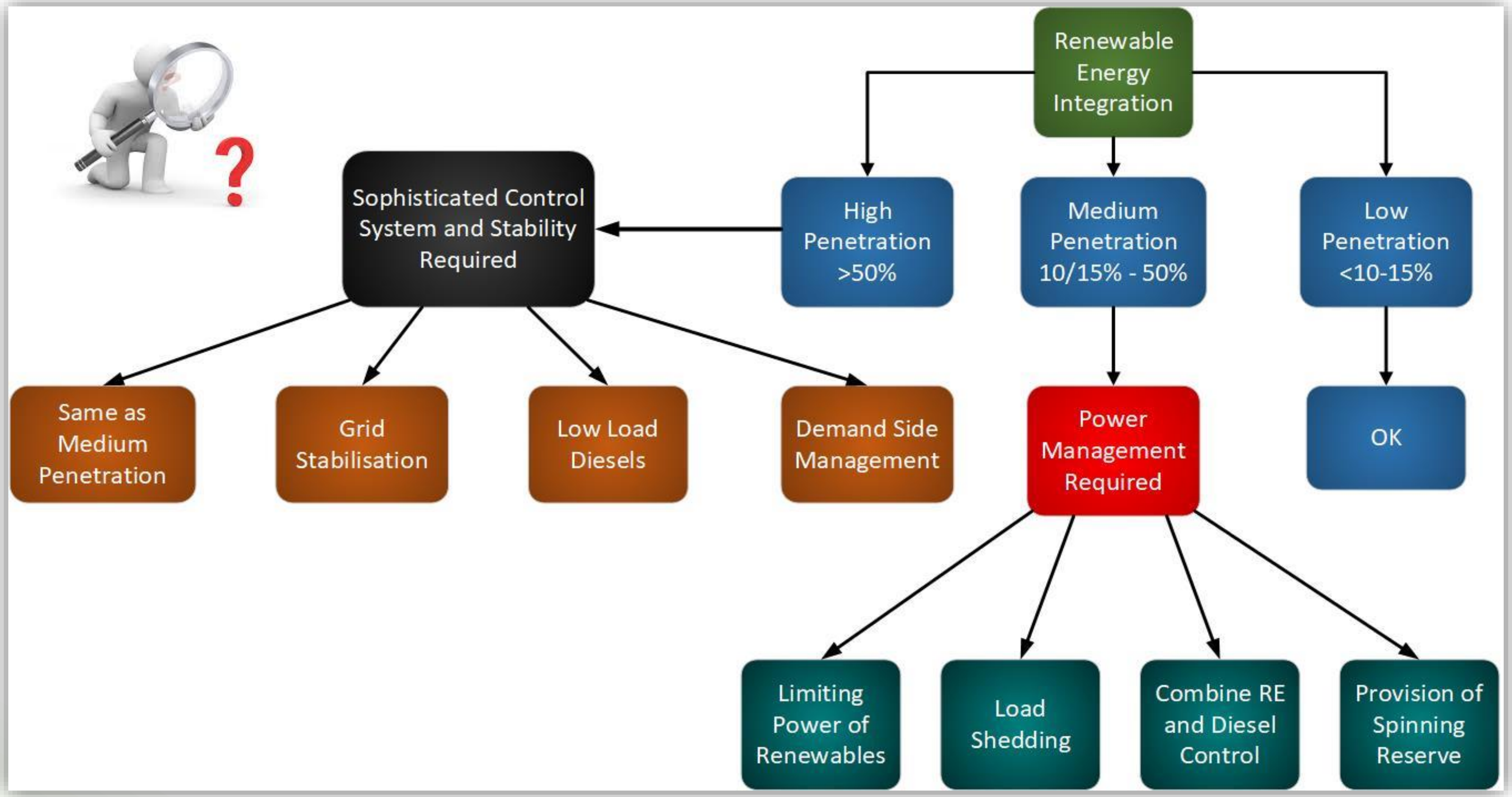
- Ancillary Services
  - System balance and frequency control.
  - Reactive power and voltage control.
- Disturbance behaviour – short circuit contribution and system protection
- Power quality
- Communications – real-time system operation (status, set-points, control signals: breakers, active and reactive, start/stop instructions)

Prioritising Technical Requirements



Energy Storage System (ESS)

Factors Influencing Selection of ESS

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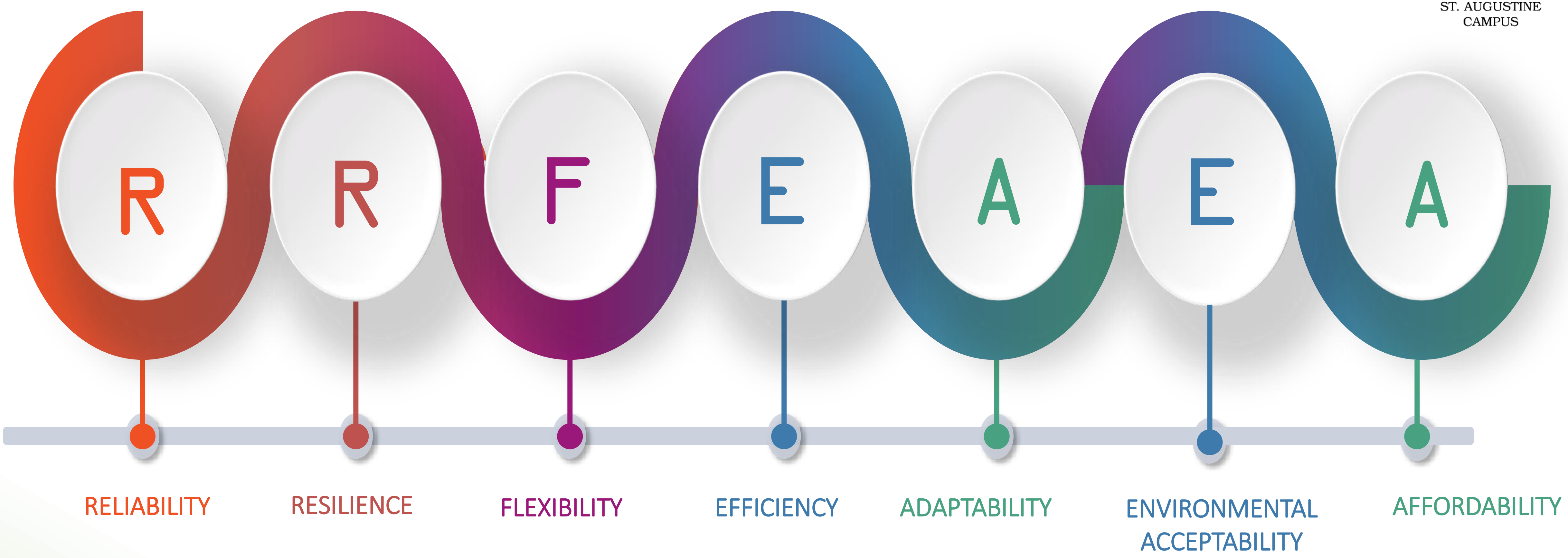


Power Vs Energy

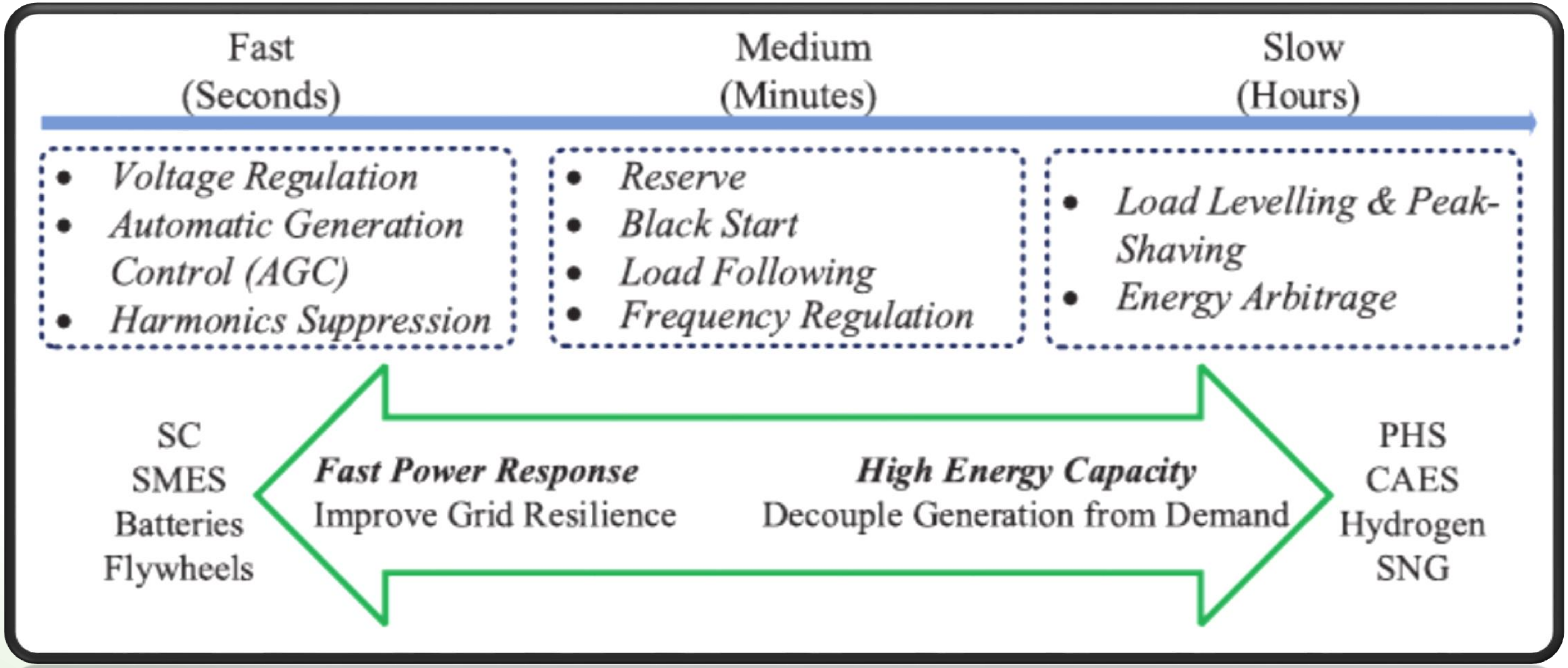
Power-oriented

- Short duration
- < 30 minutes
- Grid reliability services
- Frequency regulation
- Large shifts in the power capacity in quick, sub-hourly intervals.

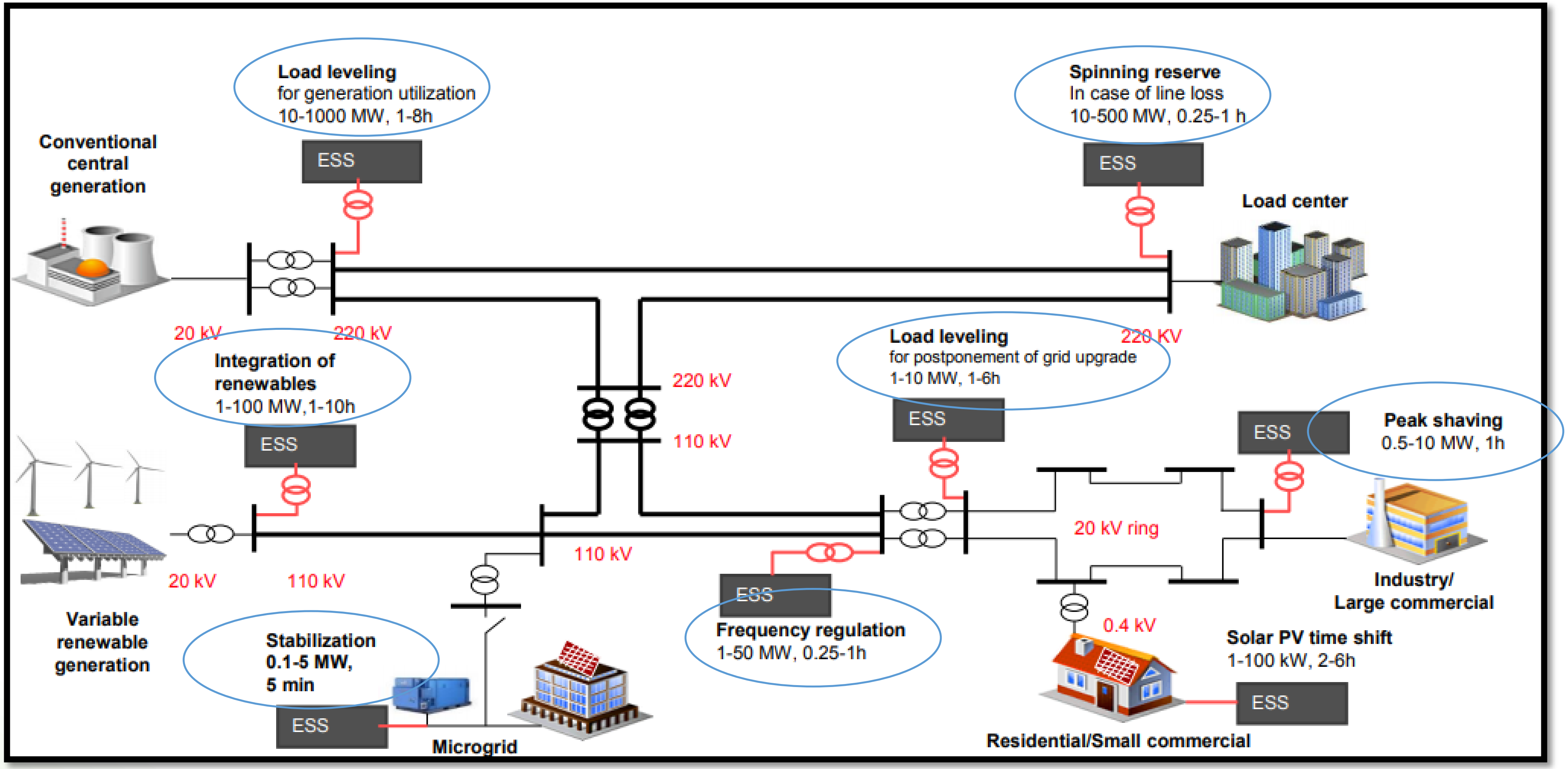
Energy-oriented

- Long duration
- > 2 hours
- Peak load shaving
- Delivering power during periods of the highest electricity demand.

ESS Support Functions



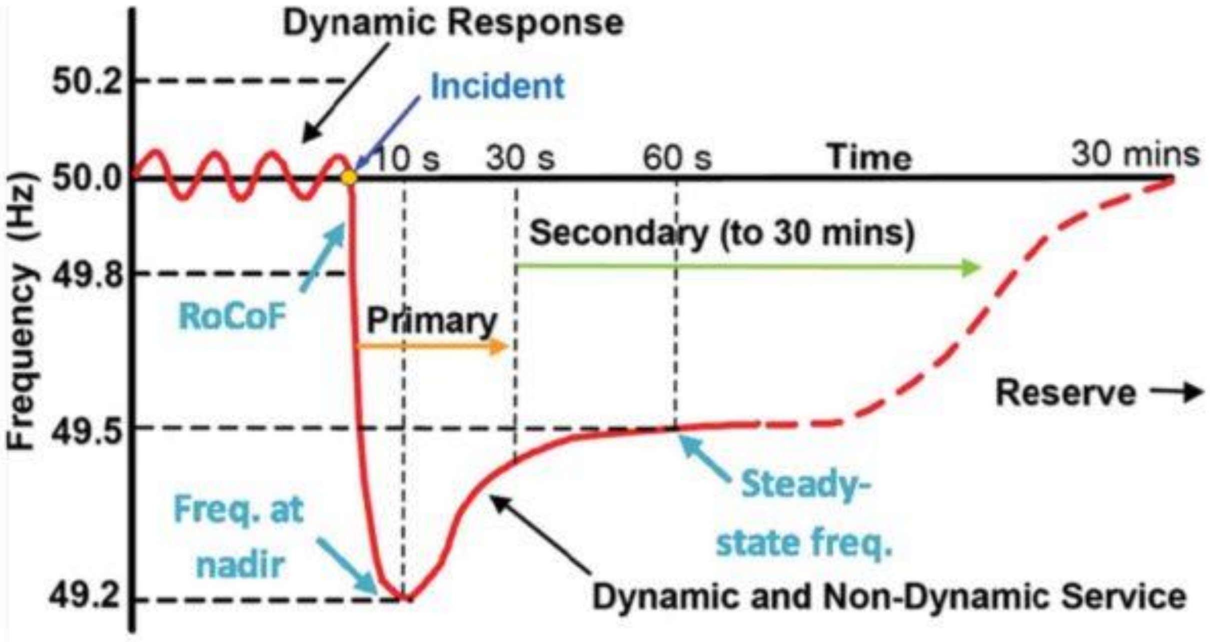
Distributed ESS



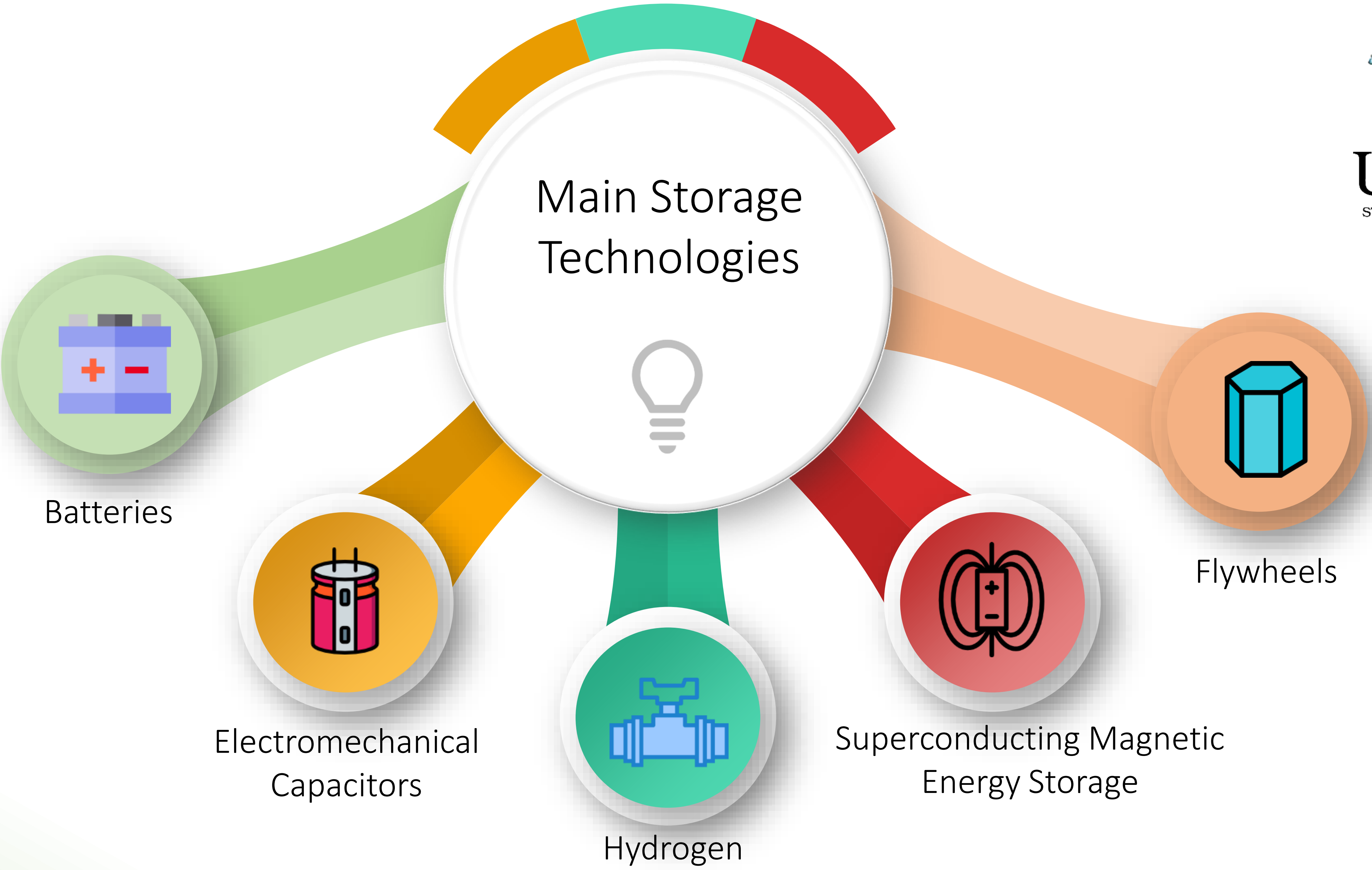
https://new.abb.com/docs/librariesprovider78/eventos/jjtts-2017/presentaciones-peru/(dario-cicio)-bess---battery-energy-storage-system.pdf?sfvrsn=2

Synthetic Inertia

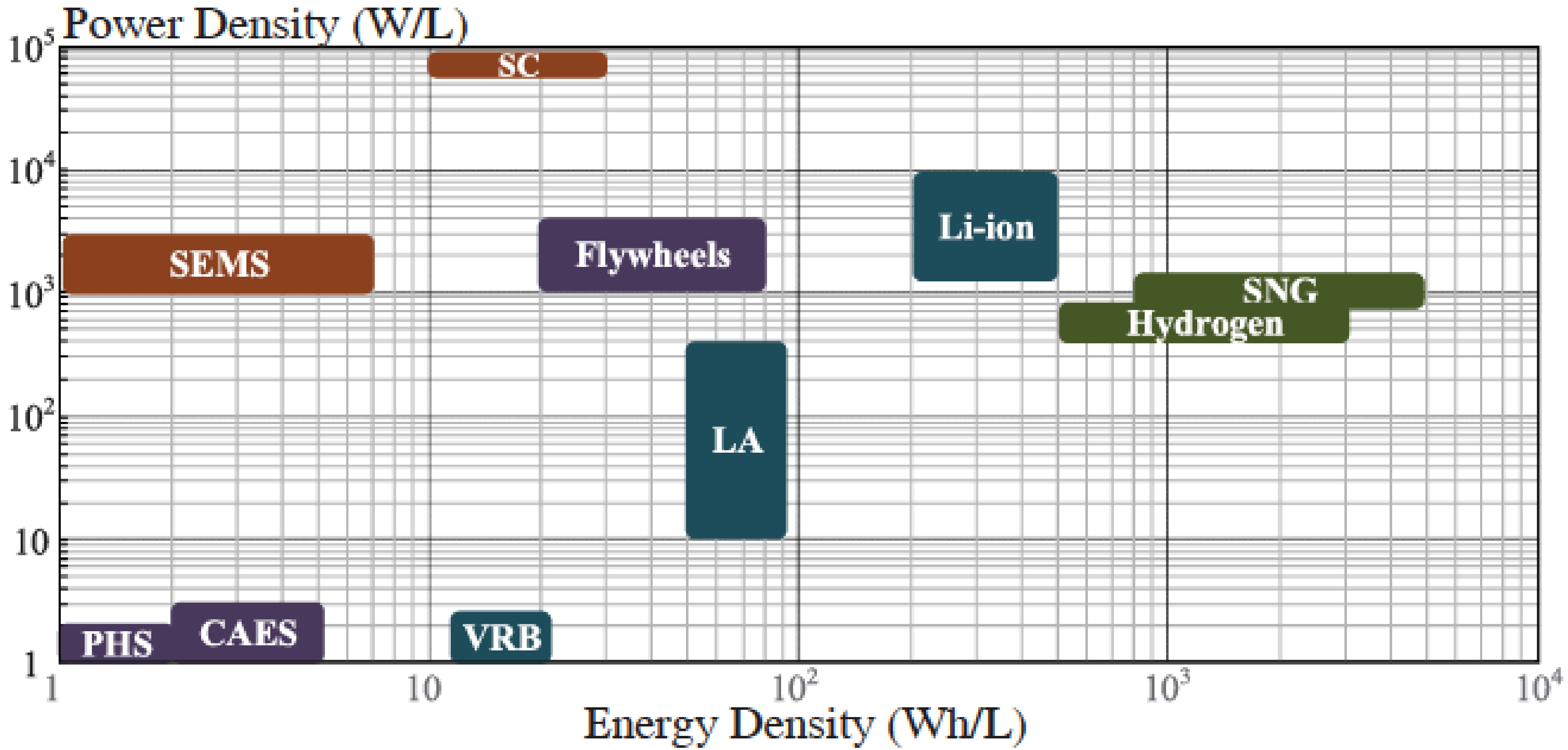
- Battery energy storage systems (BESS)
- Short-duration storage technologies for primary frequency control.
- Grid-scale batteries, respond at a much faster rate than the mechanical actions of traditional governor controls and blade pitch or wind turbine speed control mechanisms.
- Economic$.



http://www.ee.co.za/article/synthetic-inertia-grids-high-renewable-energy-content.html


Main Storage Technologies
Batteries
Electromechanical Capacitors
Hydrogen
Superconducting Magnetic Energy Storage
Flywheels

Power & Energy Densities

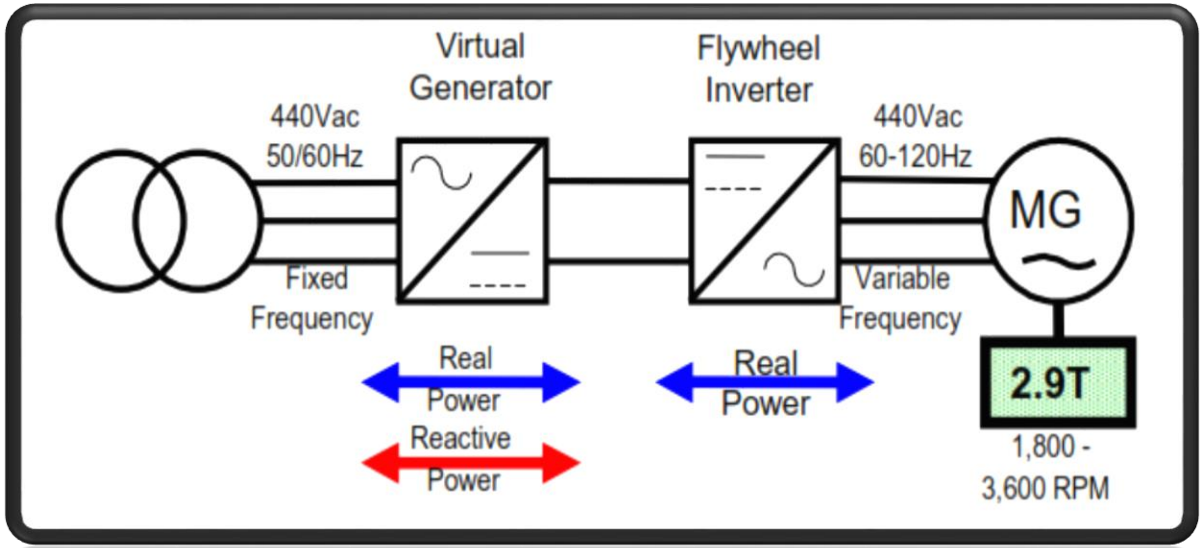


Flywheels

- Stores energy in the form of rotational kinetic energy.
- > 60,000 RPM

Flywheels

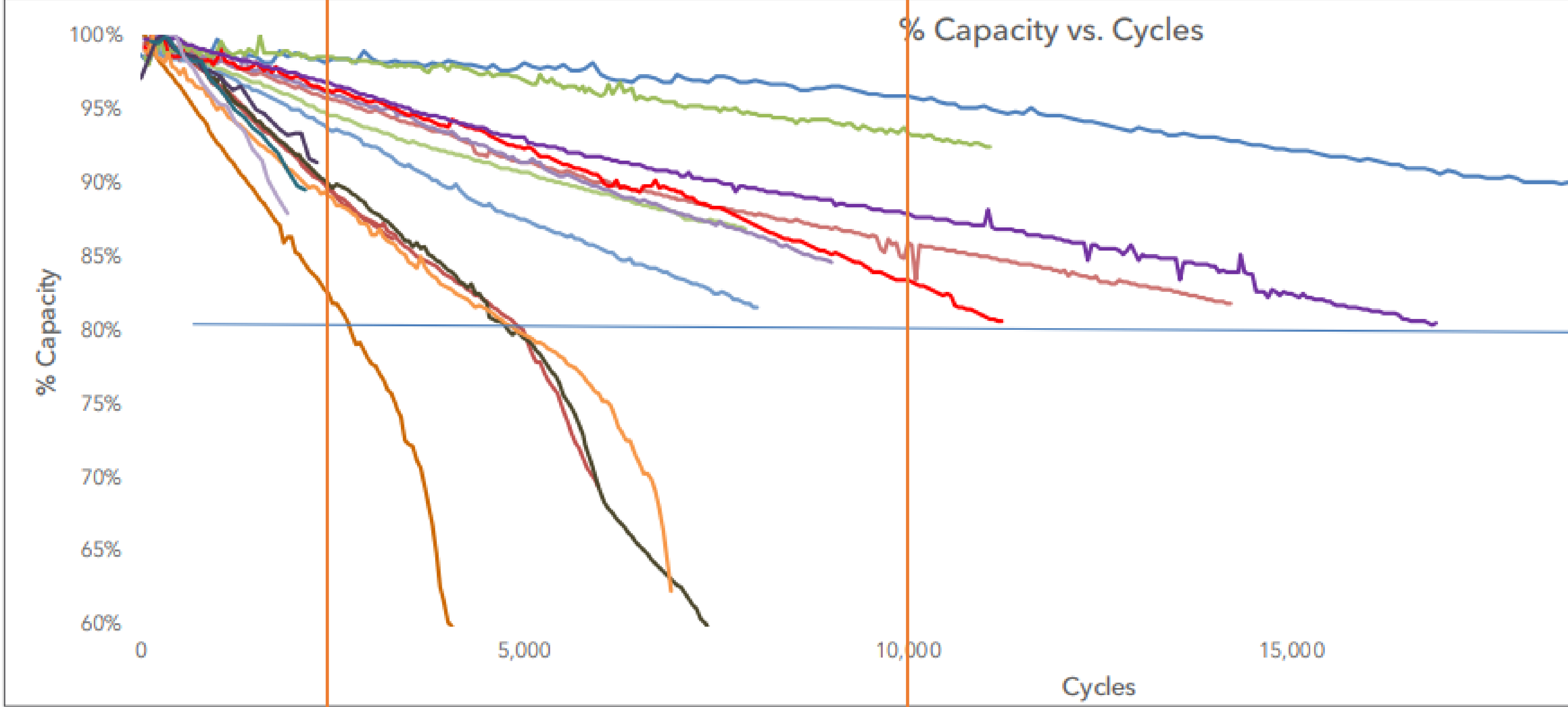
- Flywheels can work with batteries.
  - Flywheel = power-oriented.
  - Battery = energy-oriented.
- Response time exponentially faster than ramping natural gas generators (ms).
- Technology improving.
- Environmentally friendly.
- No (dis)charging capacity degradation.



Batteries

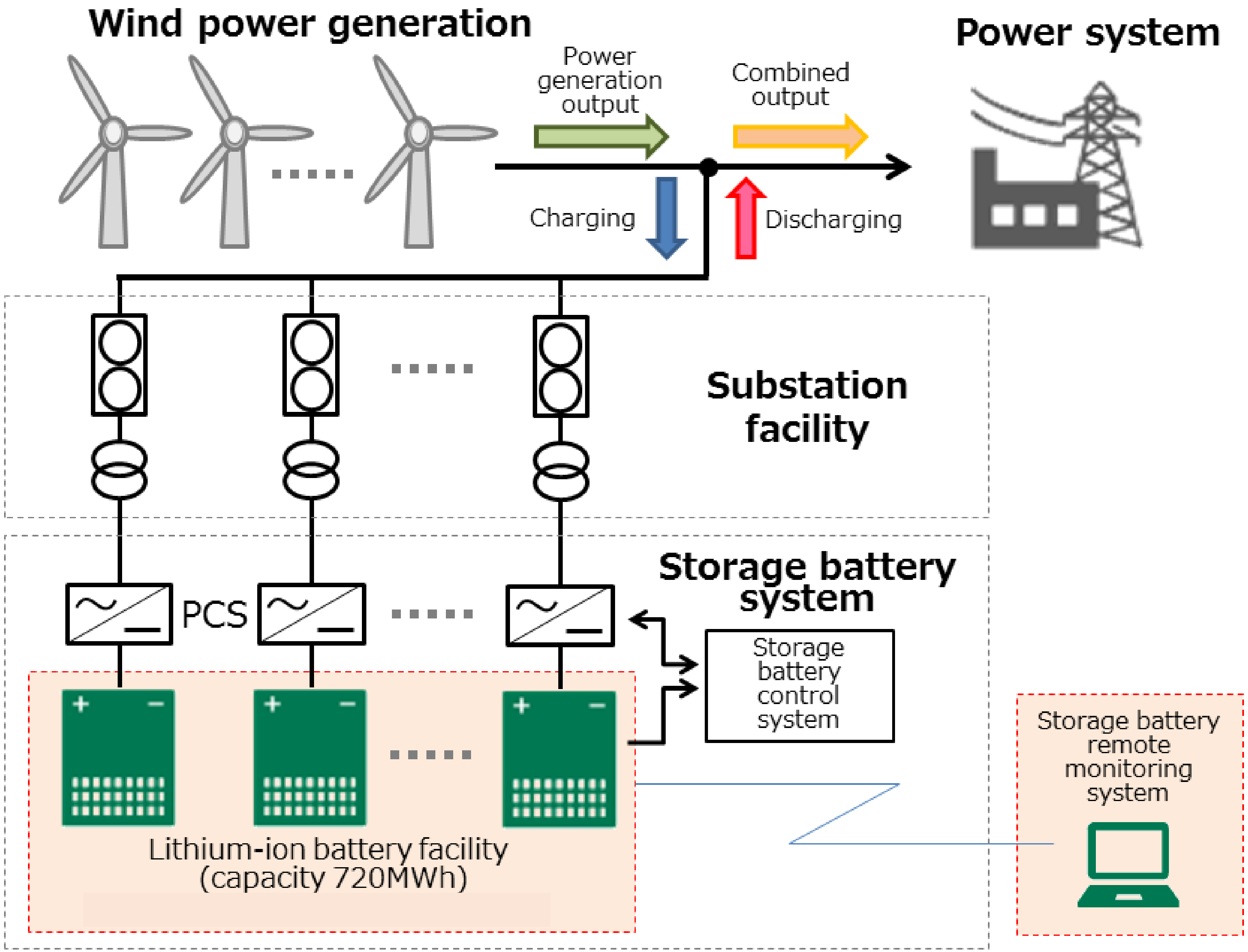
- Low maintenance (no moving parts), portable, efficiencies (65% to 85%)
- Frequency control of weak electric grid by absorbing/providing power to/from the network.
- Source of synthetic inertia.
- Lithium Ion – 30 mins to 3 hours, most cost effective energy density, highly configurable. Sophisticated BMS.
- Recycling challenges.
- Redox and Zinc-hybrid.

Lithium-Ion Battery Performance

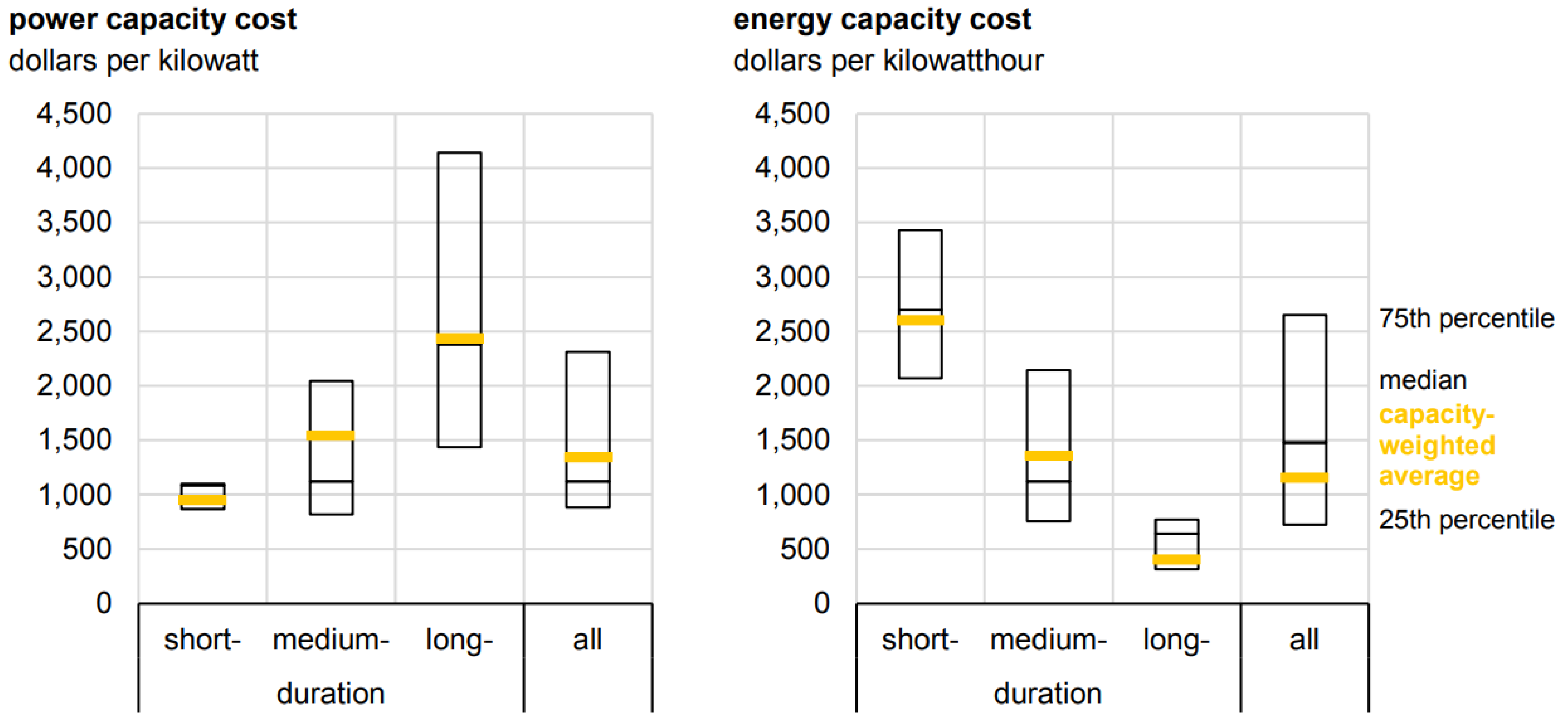


Factors:

- Average SoC
- SoC Window
- C-rate
- Temperature



- World's largest battery energy-storage system: lithium-ion 240 MW output and 720 MWh rated capacity.
- Wind-power and storage project is at Kita-Toyotomi Substation in Toyotomi, Teshio, Hokkaido, Northern Japan.
- March 2023.



Source: U.S. Energy Information Administration, Form EIA-860, *Annual Electric Generator Report*

https://www.eia.gov/todayinenergy/detail.php?id=36432

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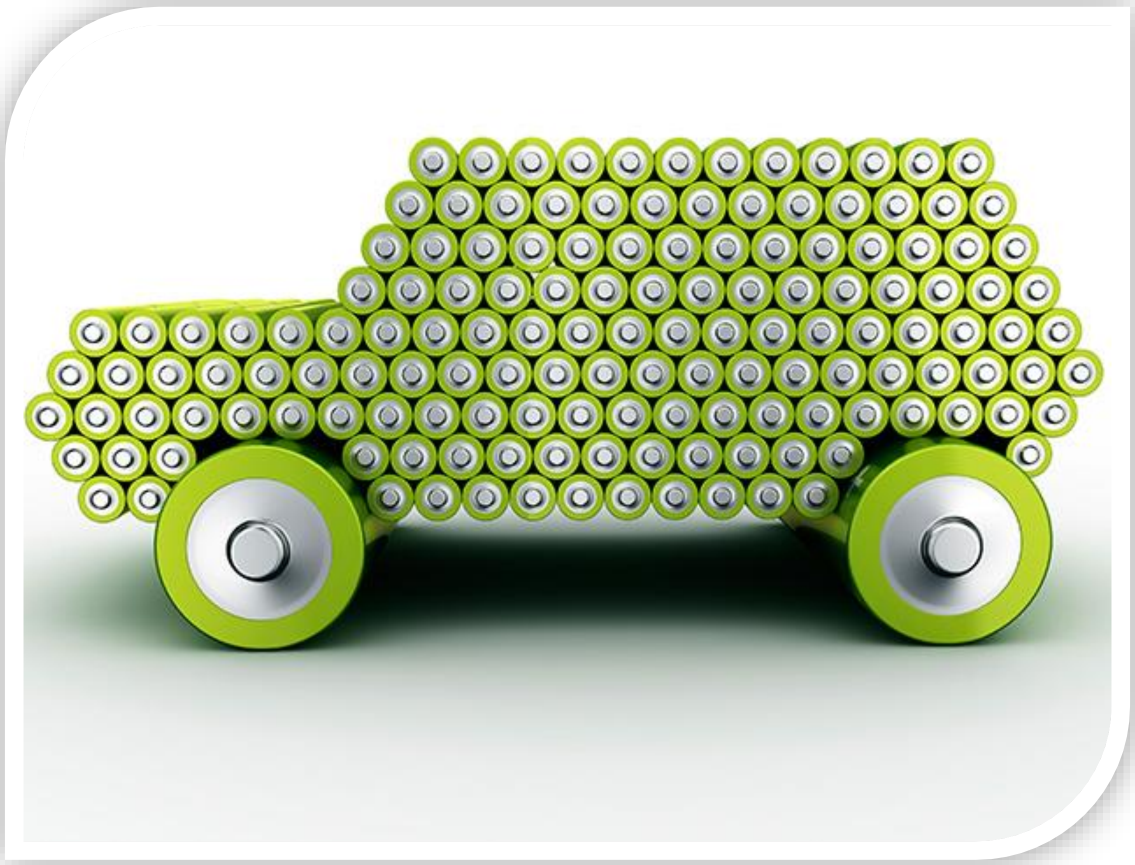
Capital cost of a utility-scale lithium-ion battery storage system sliding another 52% between 2018 and 2030. The transport and electricity sectors will benefit.

ESS Consideration Factors

- Ancillary Services (sec, mins)
- Energy Dispatch (hr)
- Optimization of:
  - Charging and discharging schedule.
  - Size and placement.
  - Spinning reserves.
- Distributed or Centralized.
- Environmental friendliness.
- Hybrid ESS.
- Economic$.



Static Synchronous Compensators (STATCOM)

- STATCOMs are regulating devices composed of a VSC that can exchange reactive power with the electrical network. Some can also supply active power.
- Functions include:
  - Reduce power fluctuations
  - Provide voltage support and damping
  - Improve transient stability
- BESS expected to act as compensators in future grid.

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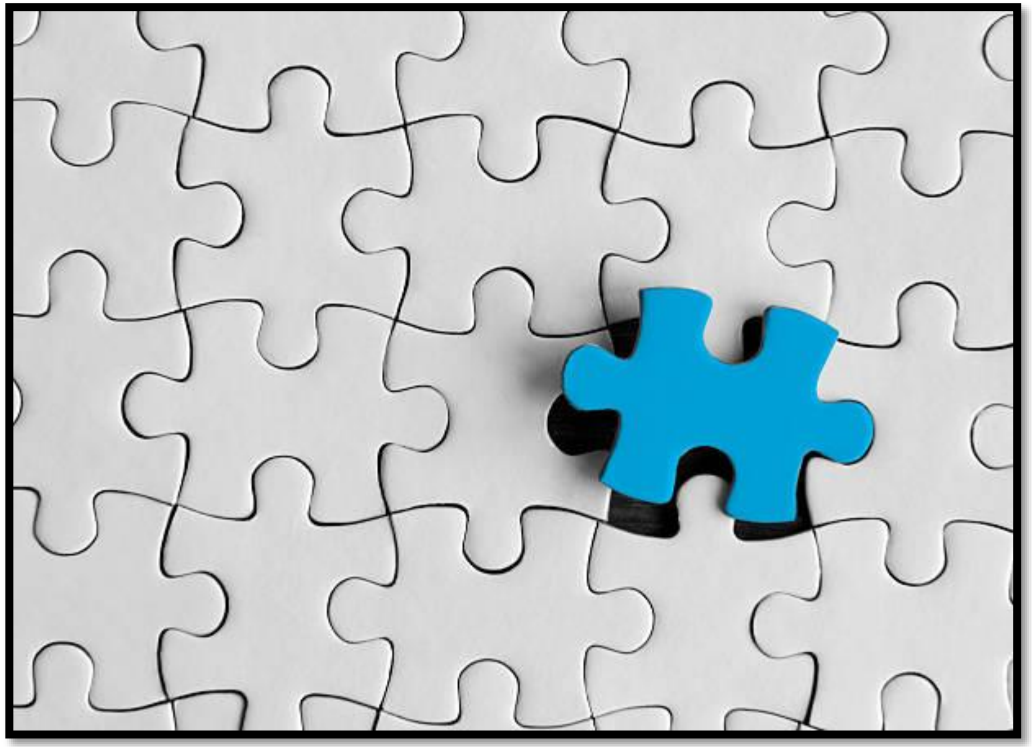
Other Technical Oriented Challenges

Technical Capacity of Staff

- Planning
  - Software familiarity
  - Missing data for models
- Operational
  - Data capture
  - Data analysis
  - Optimize
- Reduce consultant costs



Existing Models

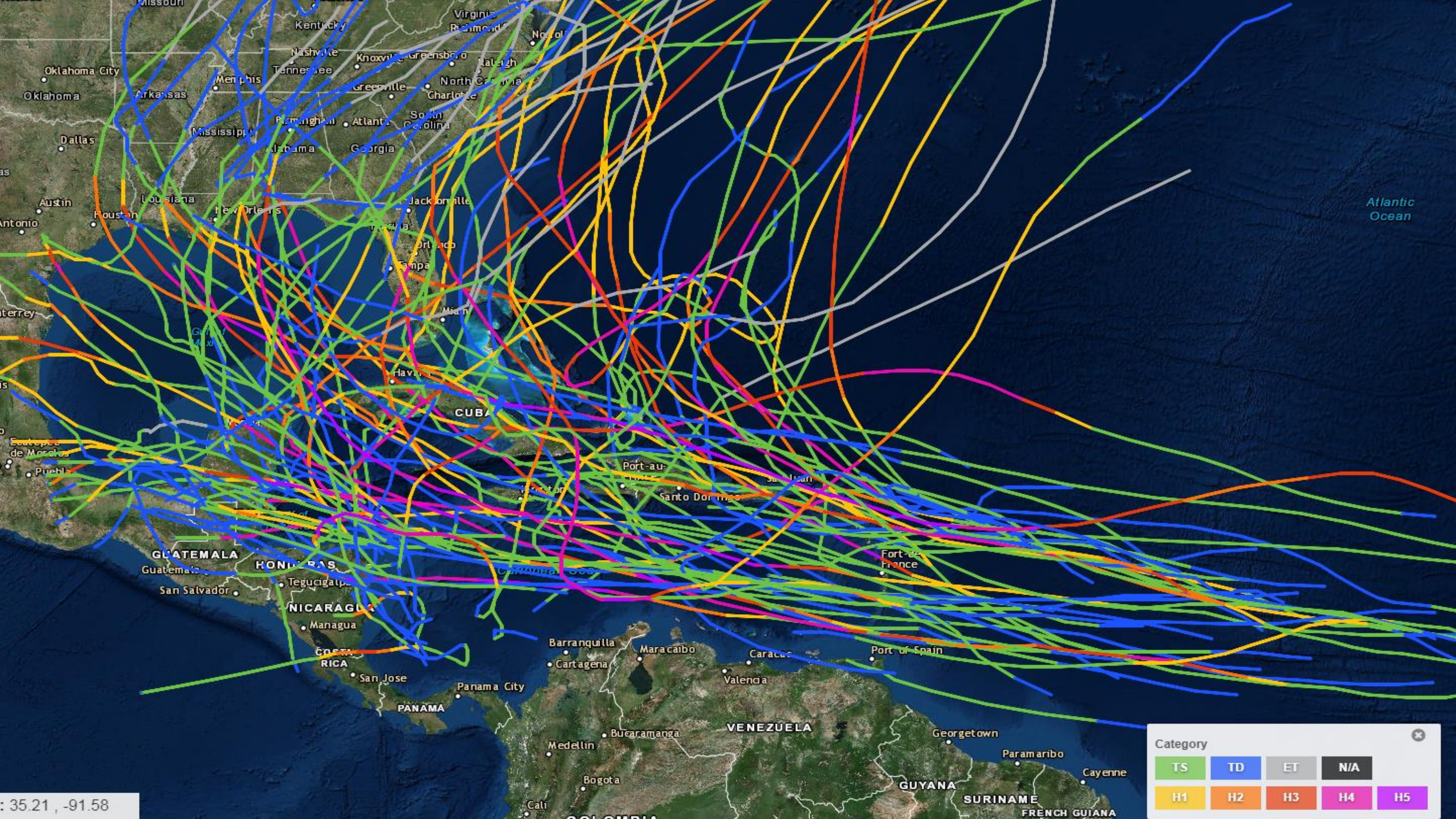
- As VRE penetration increases, the grid code is mandated to develop simulation models for the VRE plants.
- Updated network models
  - Steady state
  - Dynamic models
  - Obsolete equipment
- Software compatibility and functionality

Resilience

Resilience

Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents. Resiliency measures do not prevent damage; rather they enable electric facilities to continue operating despite damage and/or promote a rapid return to normal operations when damages and outages do occur.

Hardening and Resiliency: U.S. Energy Industry Response to Recent Hurricane Seasons (August 2010) prepared by Infrastructure Security and Energy Restoration, Office of Electricity Delivery and Energy Reliability, U.S. Department of Energy.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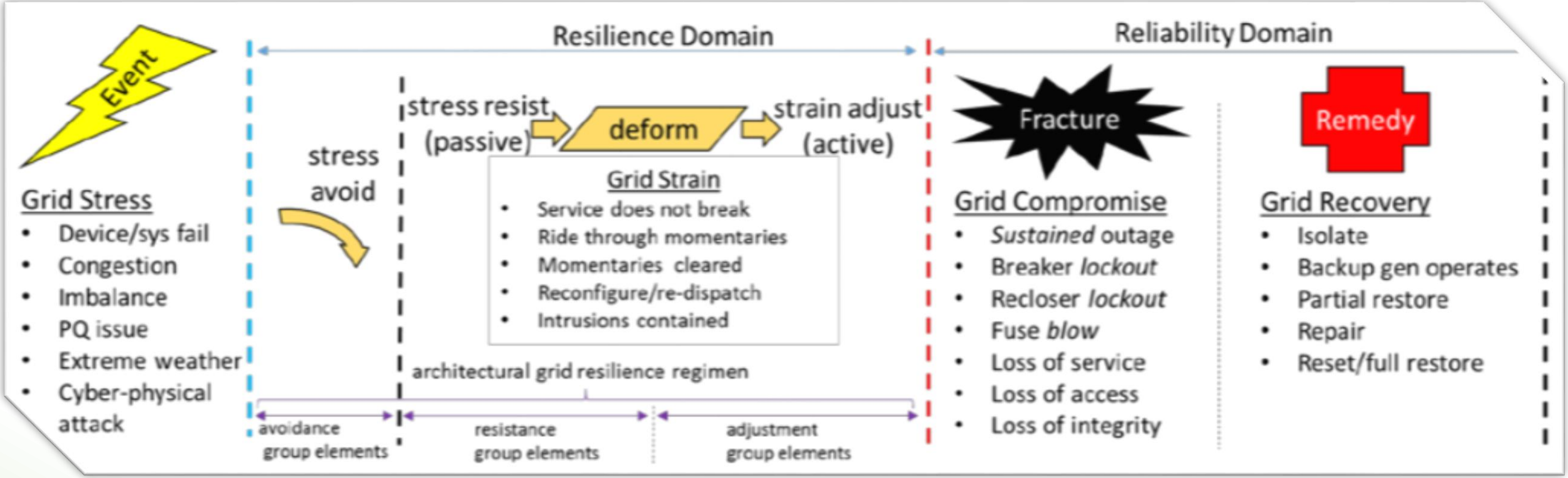
Post Disaster 2018.07.22

- Most hurricanes may encompass multiple islands and countries.
- Availability of technical expertise may not be geographically dispersed.
- Transportation and accommodation of technical crews with specialized equipment is costly, even cost prohibitive.
- In many cases technical state resources (human and equipment) may not be administratively agile to facilitate rapid deployment to affected areas.

Recommendations to CARILEC 2018.07.22

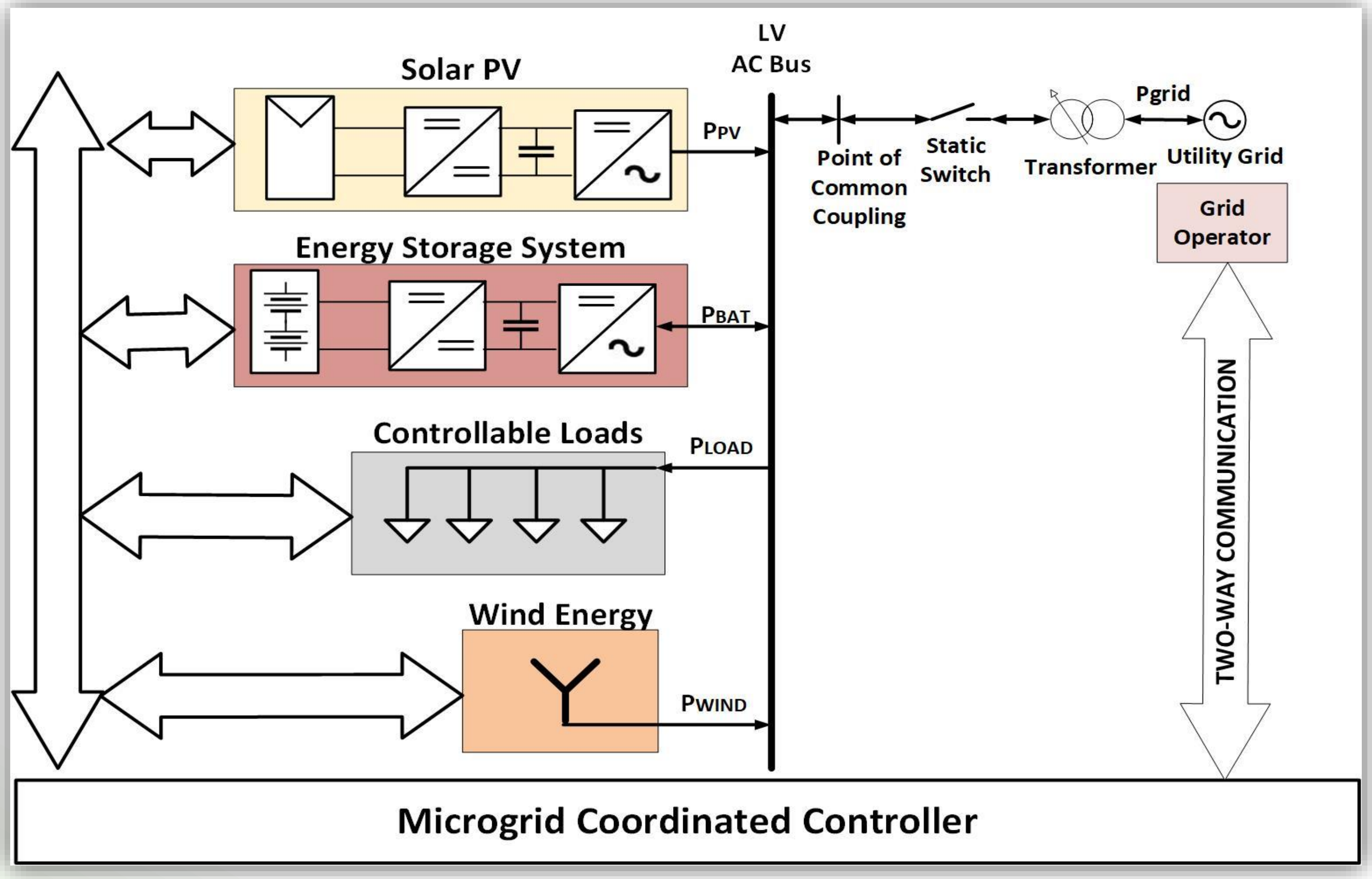
- CARICOM fund to engages private sector for technical services.
- CARILEC led detailed and updated spares inventory based on technical specifications (voltage, kVA, Hz) identifying nearest location in region.
- Possible formation of a regional body similar to NERC.
- CARILEC led post natural disaster best practice protocol/manual.
- University led development of a basic post natural disaster testing toolkit. Minimal resources to yield reasonable asset status.
- Utilities to ensure institutional knowledge is not lost.

Resilience and Reliability Domains



https://gridmod.labworks.org/sites/default/files/resources/Theory%20of%20Grid%20Resilience%20final_GMLC_0.pdf

Typical Microgrid



- Critical facilities, areas/regions powered after a (natural) disaster.
- Create electrical islands.
- Biggest challenge is protecting the assets.

Conclusions

- Many technical considerations for RE integration – there is a method!
- Energy storage requirements must be carefully con$idered.
- Resilient oriented options.
- Microgrids create electrical islands within an island.
- Opportunity to learn from others and continue to develop regional capacity.

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Thank You

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