

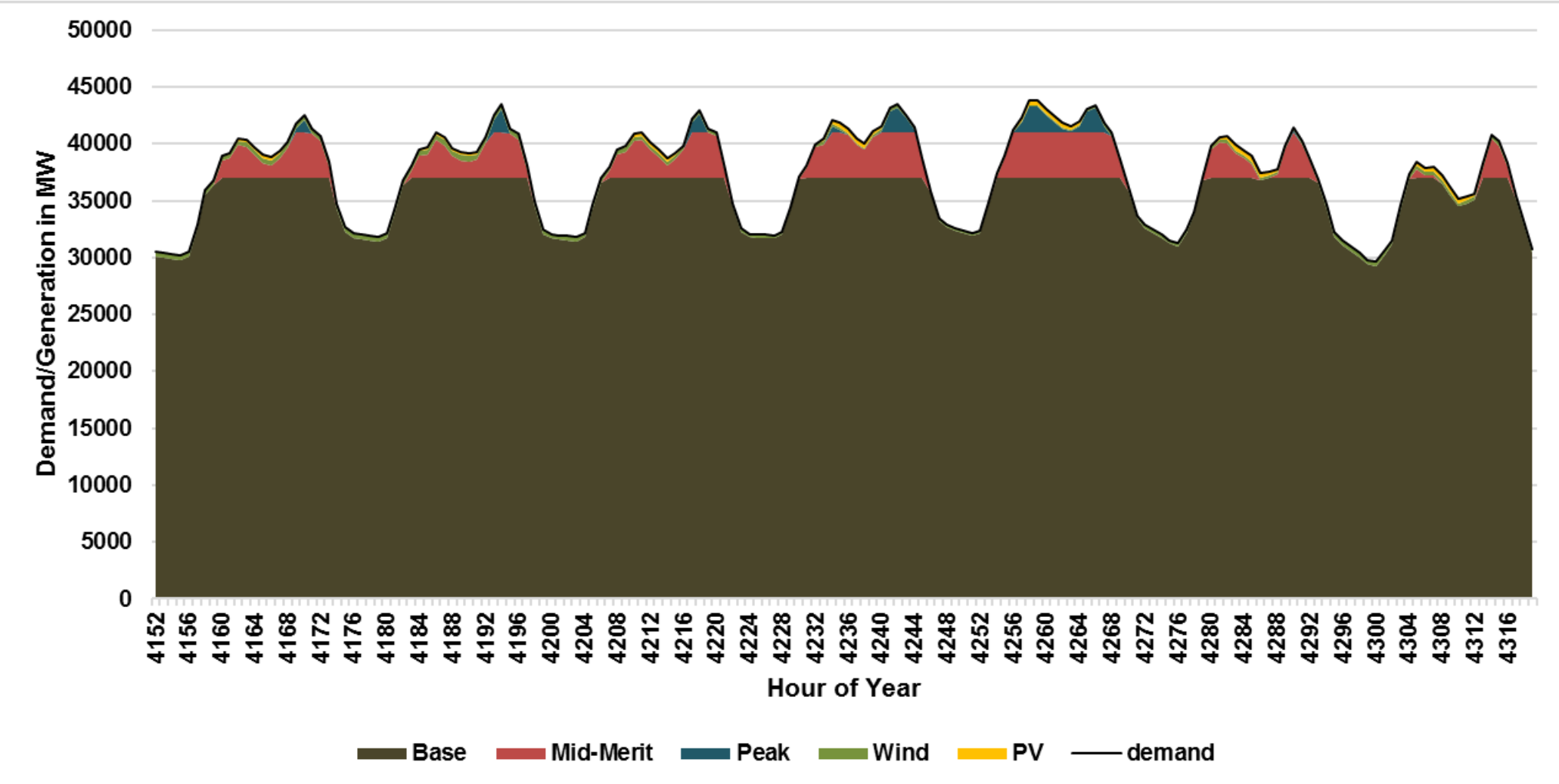
# Power systems with very large wind and solar generation - what is needed for a stable and secure operation?



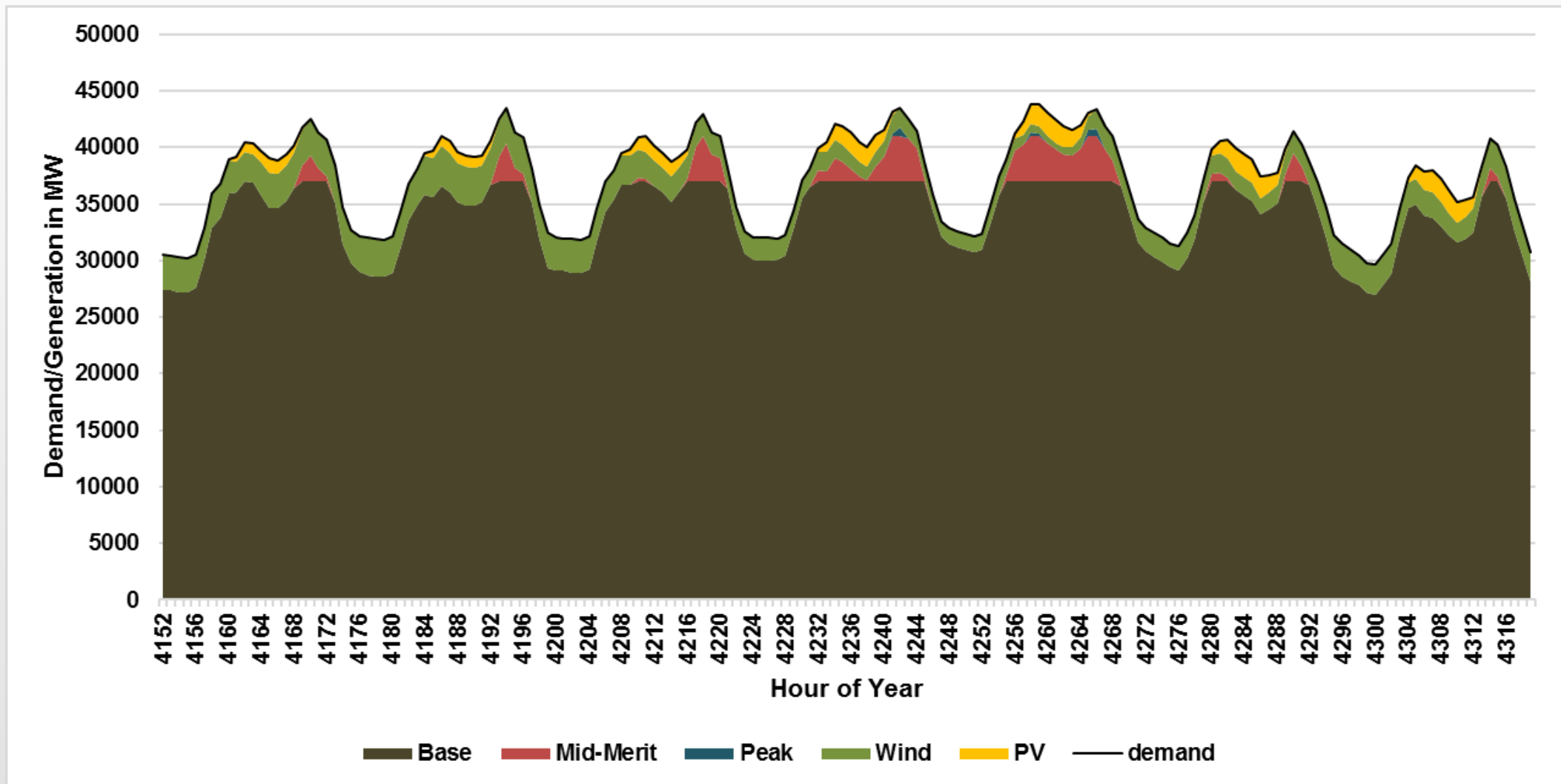
Dr.-Ing. Markus Pöller - MOELLER & POELLER ENGINEERING (MPE)

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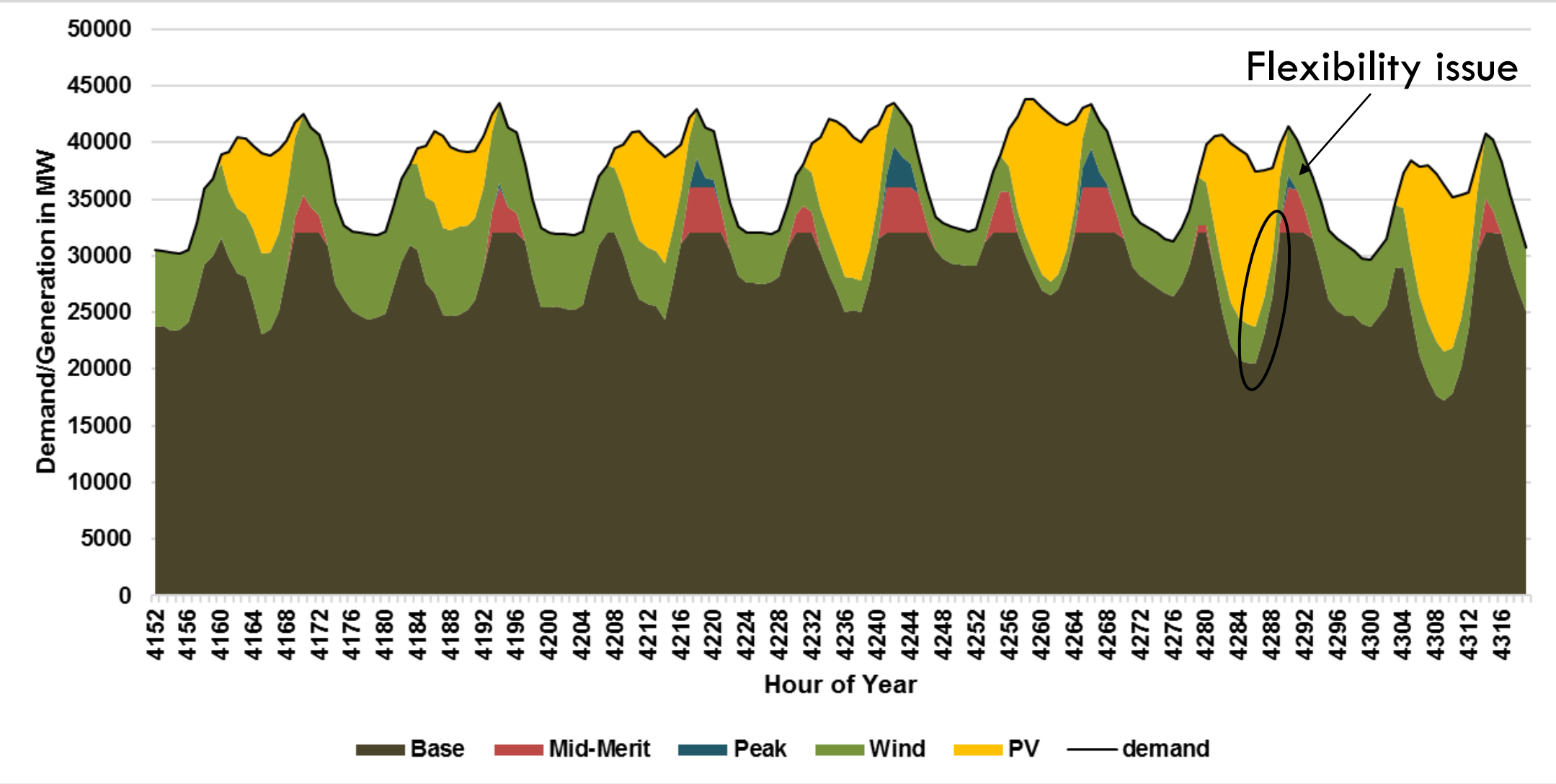
# Phase 1 – First VRE installations



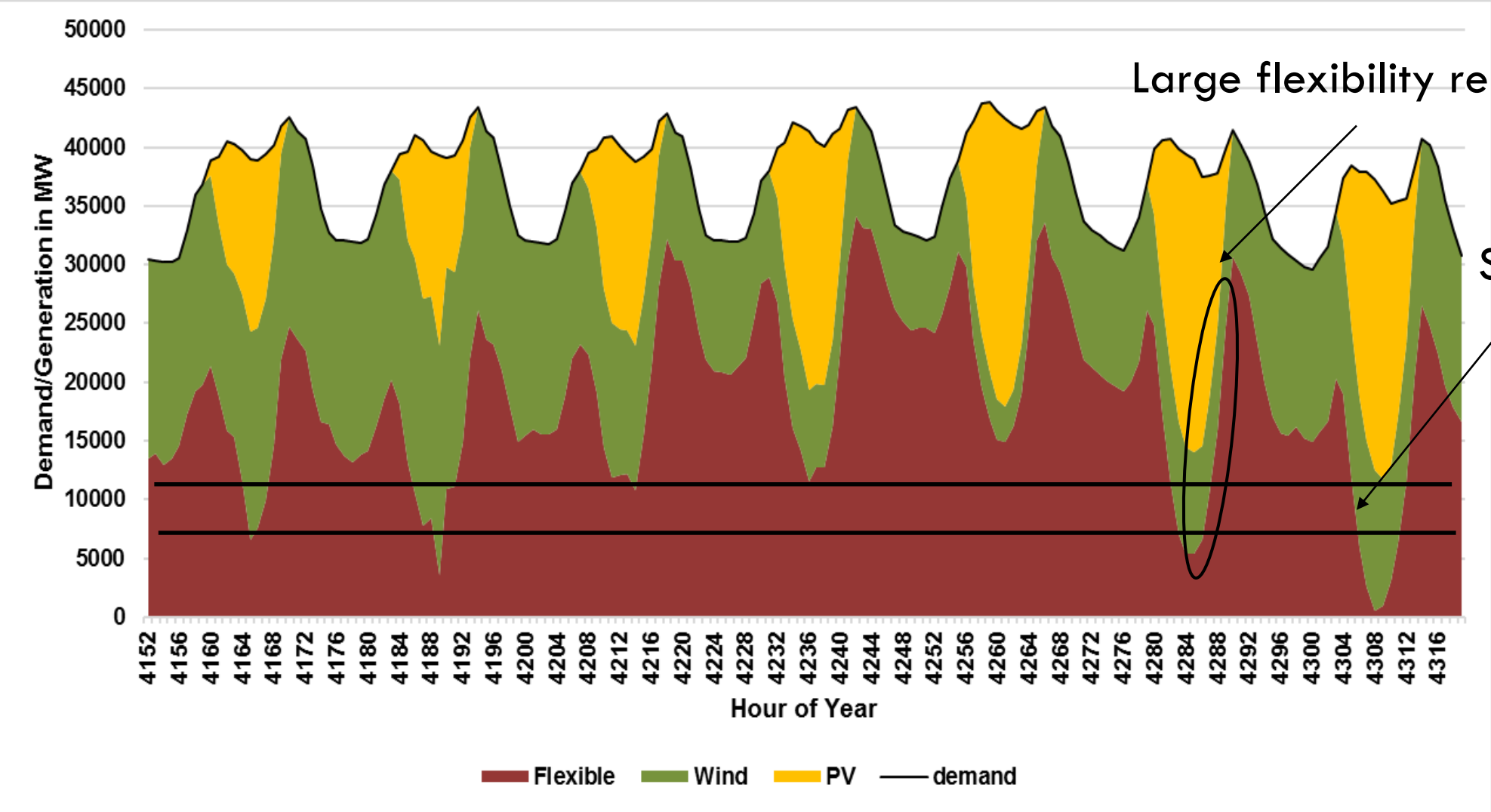
# Phase 2 – VRE noticeable at system level



# Phase 3 – Flexibility becomes a priority



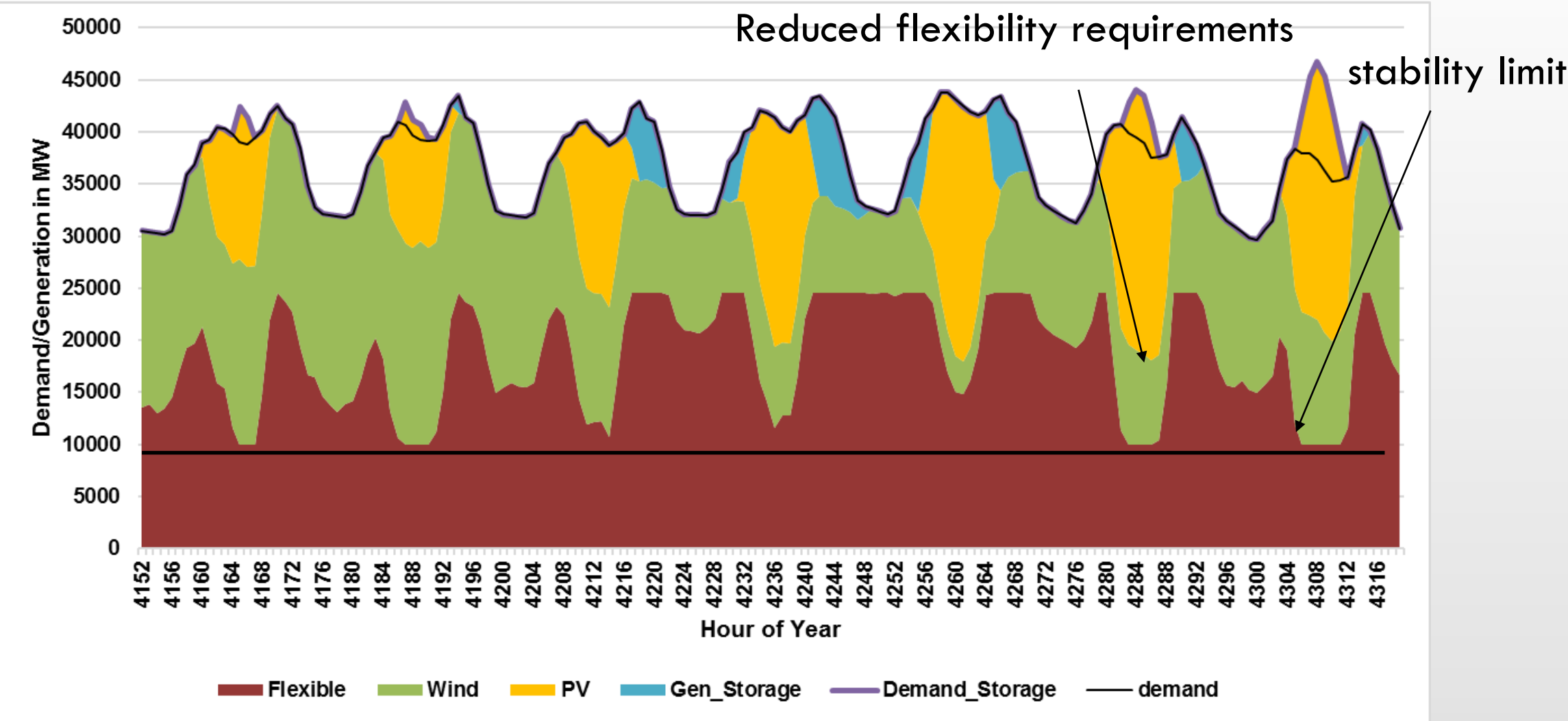
# Phase 4 – (Frequency) Stability becomes an issue



Large flexibility requirements

Stability limits

# Phase 4 – with Storage



# The four phases of VRE deployment

Phase 1:  
First installations

- VRE not noticeable at system level
- System operations not affected
- Only local grid issues

Phase 2:  
VRE noticeable at system level

- VRE becomes noticeable to the system operator
- VRE forecast should be introduced
- VRE has impact on power plant dispatch (electricity market)

Phase 3:  
Flexibility becomes relevant

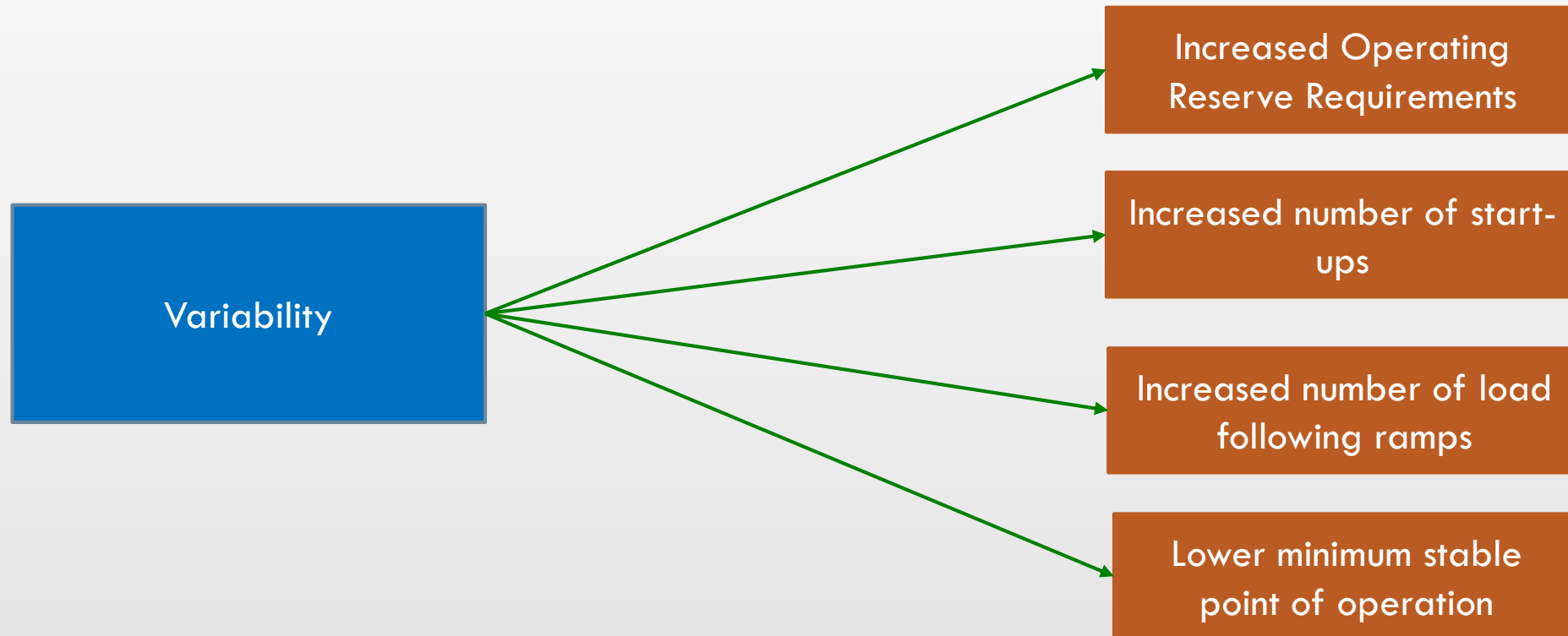
- Power plant dispatch highly influenced by VRE
- VRE forecast essential
- VRE must contribute to ancillary services
- Flexible, dispatchable power plants are required

Phase 4:  
Stability becomes relevant

- All dispatchable power plants must be flexible
- System characteristics are dominated by VRE
- VRE limited by stability constraints

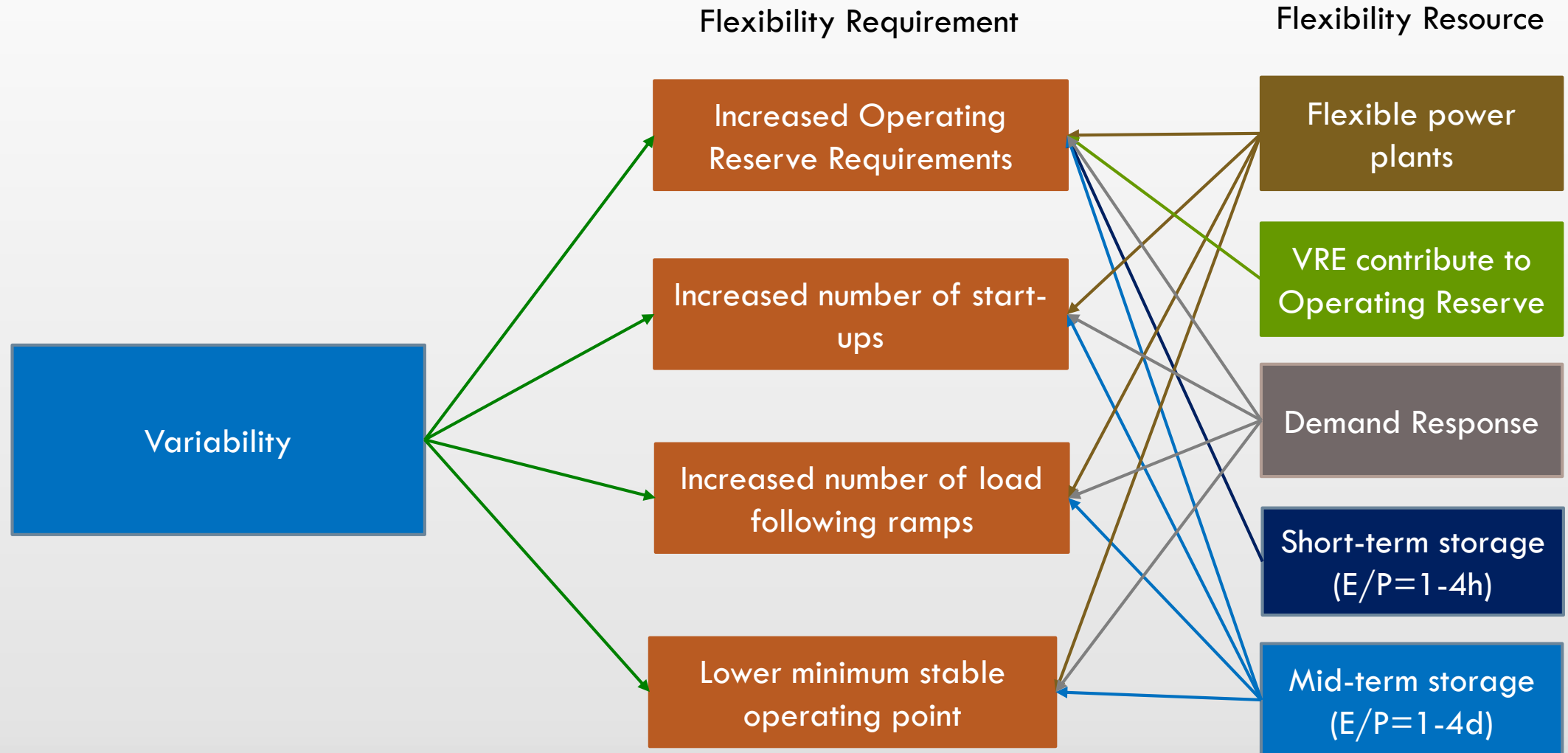
*According to: IEA: Getting Wind and Sun onto the grid – A manual for policy makers*

# Potential flexibility issues in systems with high VRE

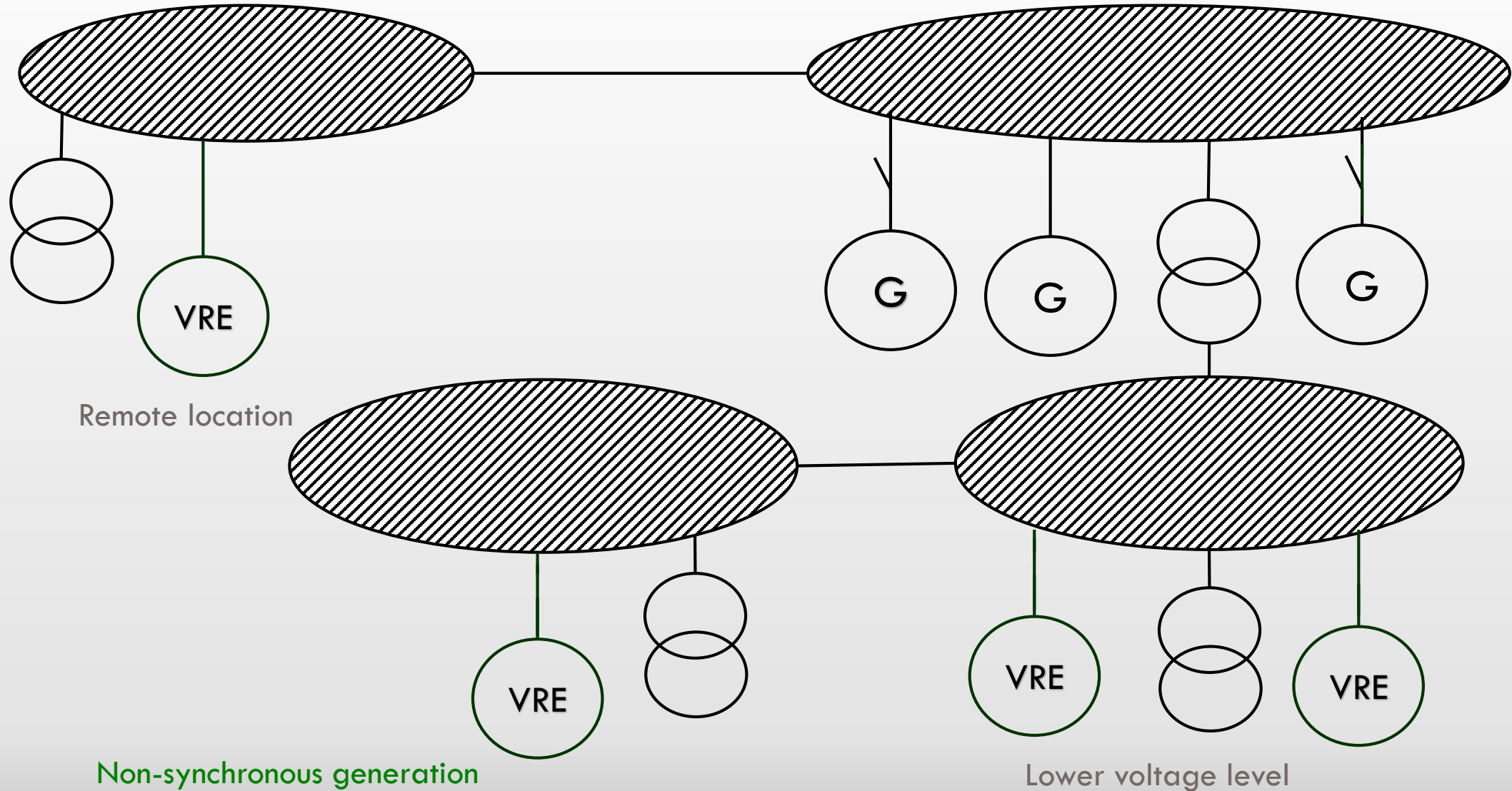




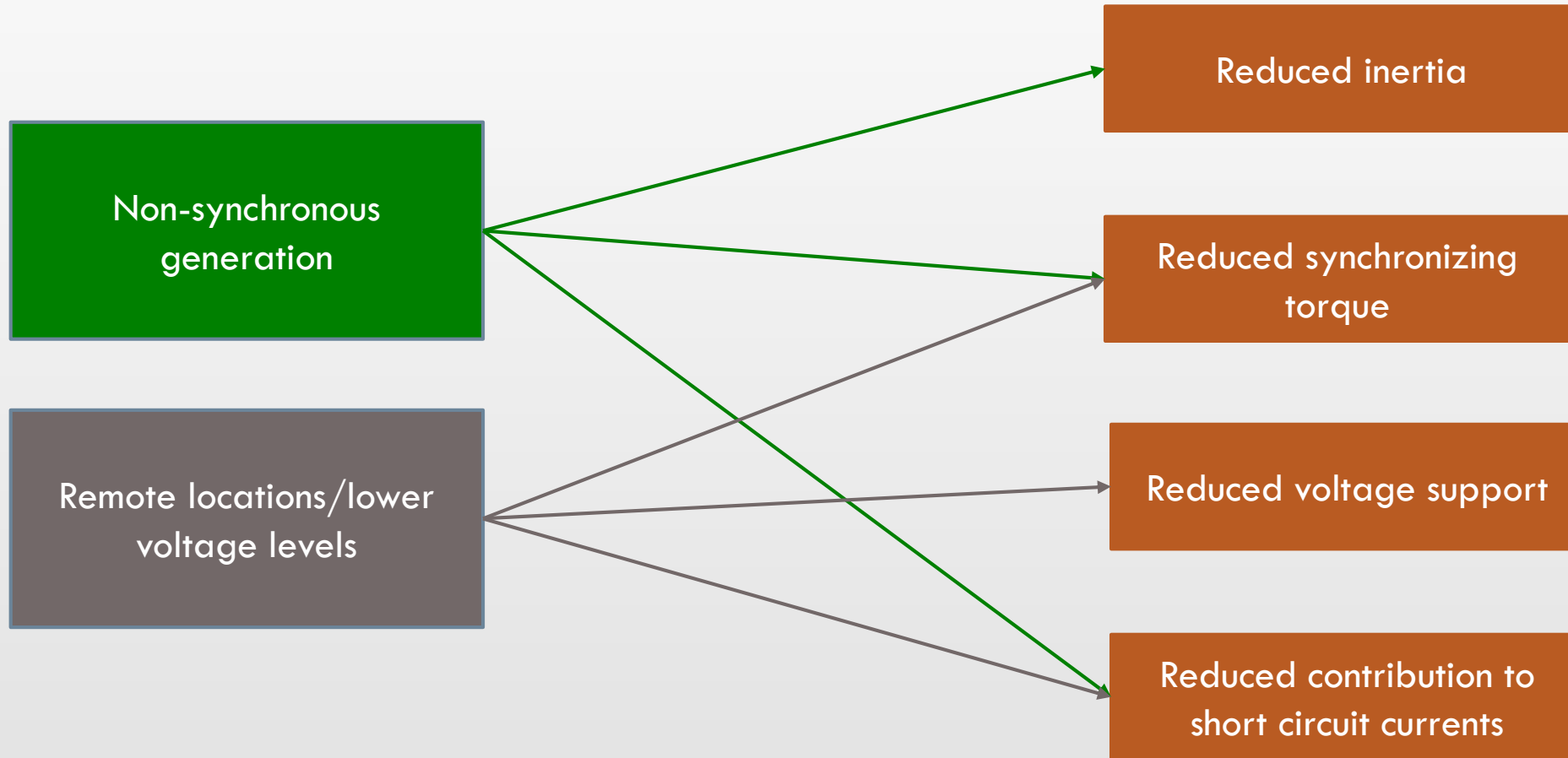
# Flexibility issues and solutions



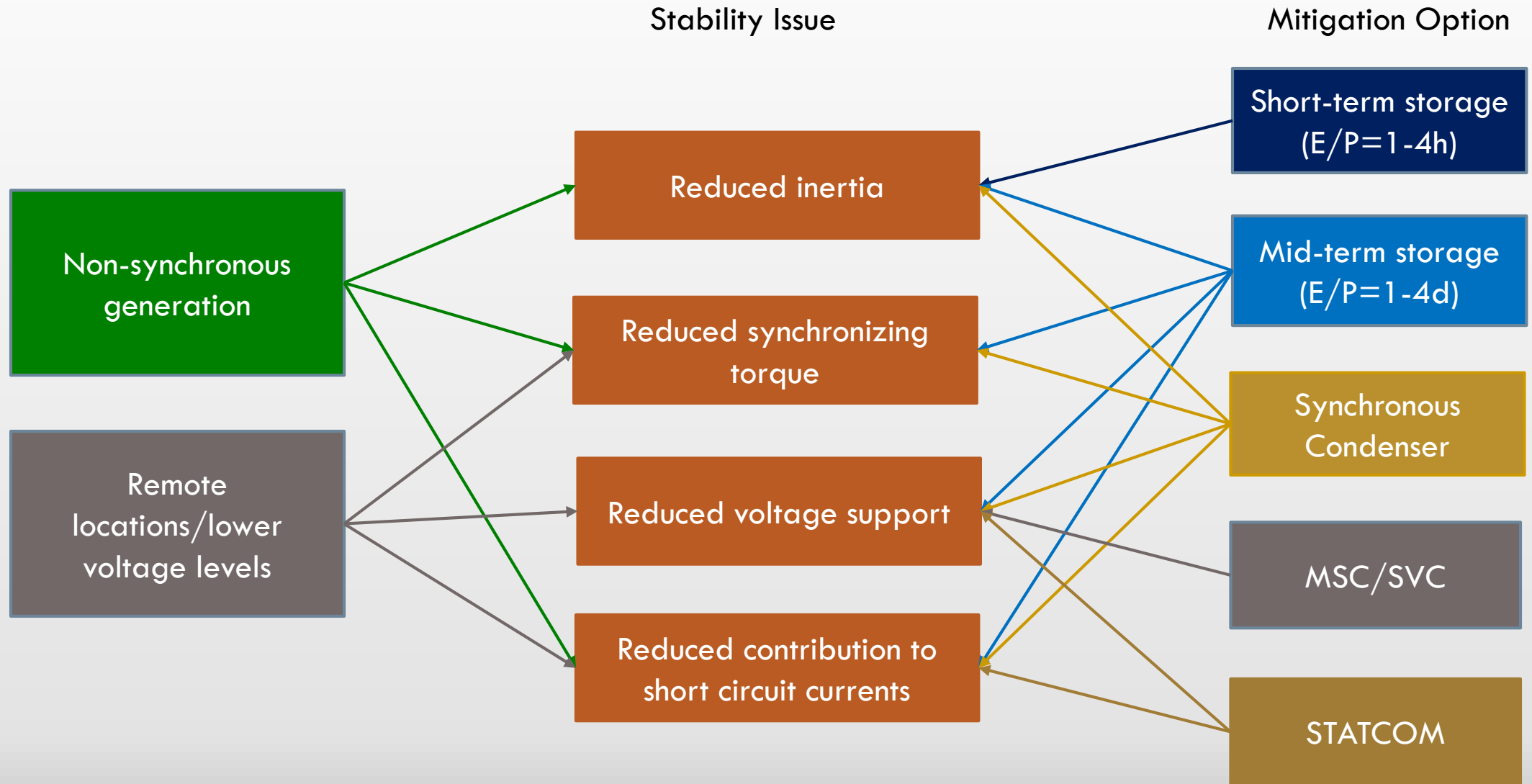
# Stability - Systems with large VRE share – What's different?



# Potential stability issues in systems with high VRE



# Stability issues and solutions



# And beyond phase 4?

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## **Phase 5 is characterised by occasional excess of VRE generation**

- Mid-term storage required for avoiding PV and wind curtailments.

## **Phase 6 is characterized by (almost) 100% VRE**

- Long-term storage ( $E/P > 1$  month) is required for compensating monthly/seasonal variations of wind and PV

# How storage supports systems with large share of VRE

## Short-Term Storage (E/P=1-4h, e.g. super-caps, flywheel, battery):

- Provision of fast (enhanced) frequency control
- Provision of Instantaneous Reserve
- Provision of Regulating and 10-Minute Reserve

Today's applications in e.g.  
U.K. or Germany



## Mid-Term Storage (E/P=1-4d, e.g. battery, flow battery, pumped-hydro):

- Increases the minimum level of synchronous generation in the system, which mitigates numerous stability issues.
- Reduces flexibility requirements of dispatchable power plants (ramping, start-ups)
- Can contribute to the equivalent firm capacity (Capacity Credit)

## Long-Term Storage (E/P>1 month, e.g. hydrogen, methane):

- Balances long-term (weekly/monthly/seasonal) variations of VRE
- Mandatory required in systems with (almost) 100% VRE

## The future power system needs flexibility

### Flexibility can be provided by:

- Flexible power plants (e.g. gas turbine generators)
- Demand response
- Storage

## Storage can provide flexibility and stability