# WAMS/WACS in Iceland

NASPI Work Group Virtual Meeting

October 7, 2021

Birkir Heimisson

LANDSNET

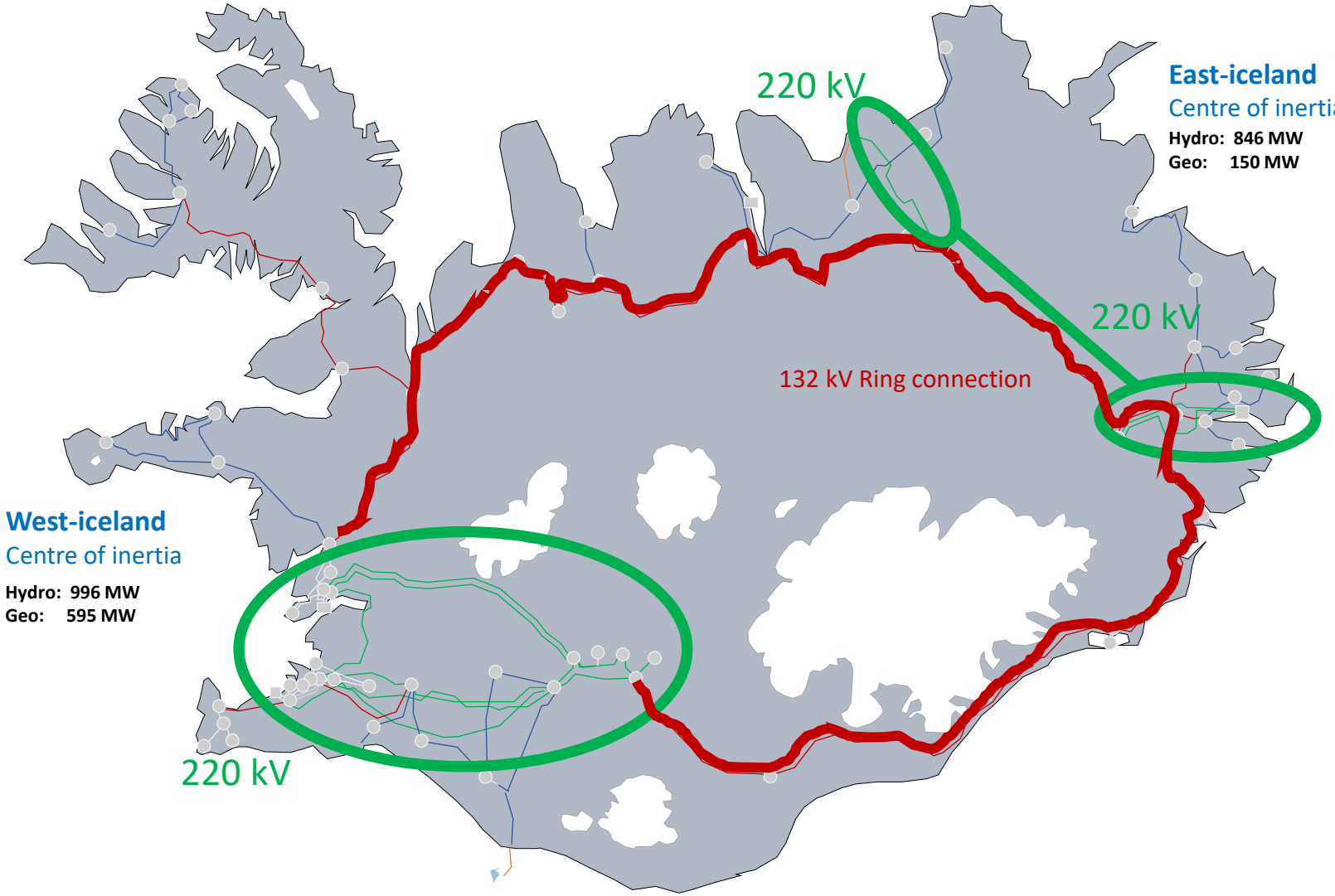
# Icelandic Transmission System

Load peak: **2400** MW

Total Energy: **17.7** GWh/year

**100%** Renewable energy:
**70%** Hydro
**30%** Geothermal

Power intensive users
~**80%** of total load




The grid includes more than 3,000km of transmission lines and about 76 substations

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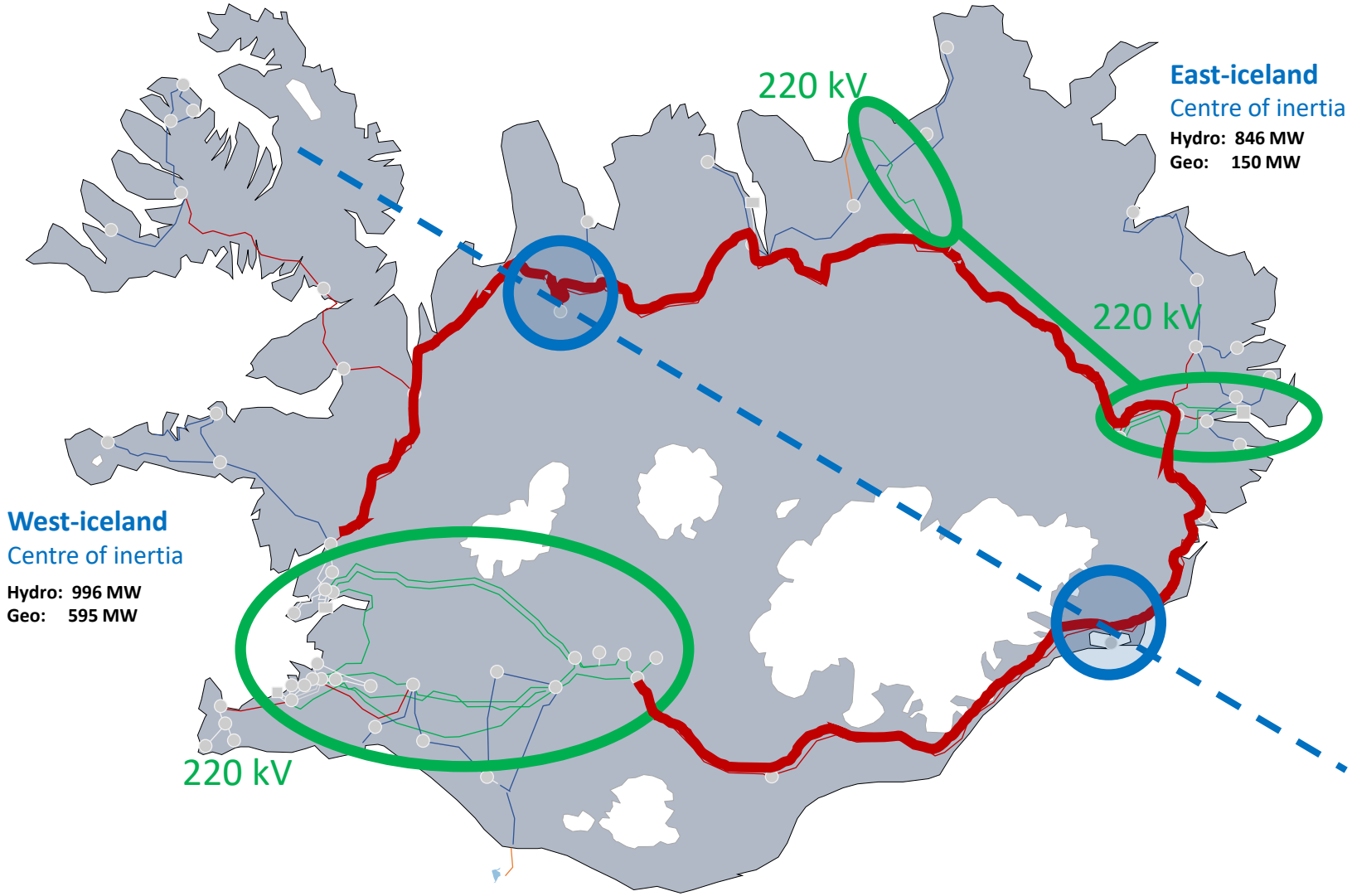


The grid includes more than 3,000km of transmission lines and about 70 substations

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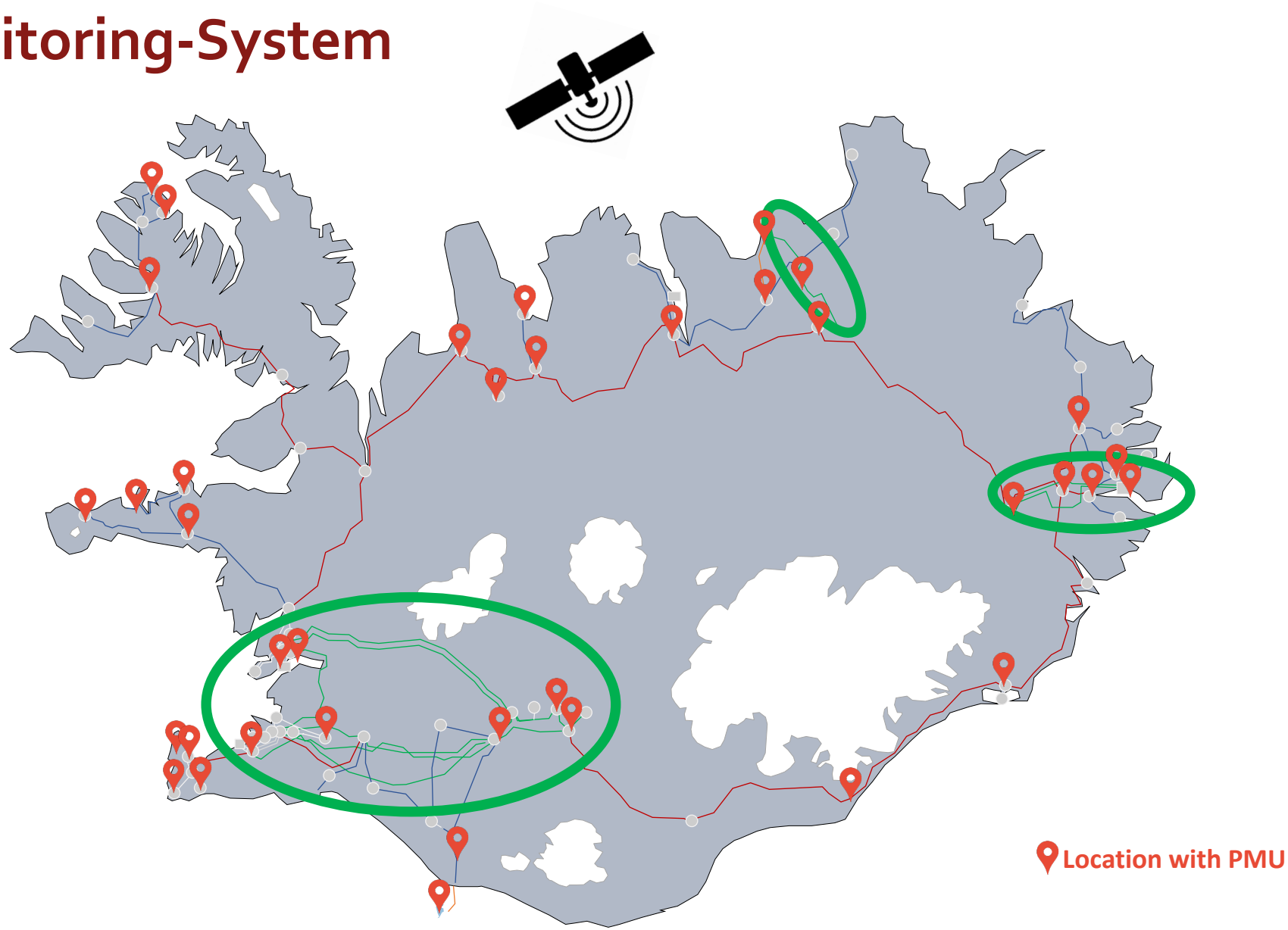
# Wide-Area-Monitoring-System

- Extensive WAMS monitoring & records (~80 PMUs)
- Good quality communications network
- Landsnet & grid-stakeholders willing to trial innovation
- New control is measurable on small system



# Why WAMS?

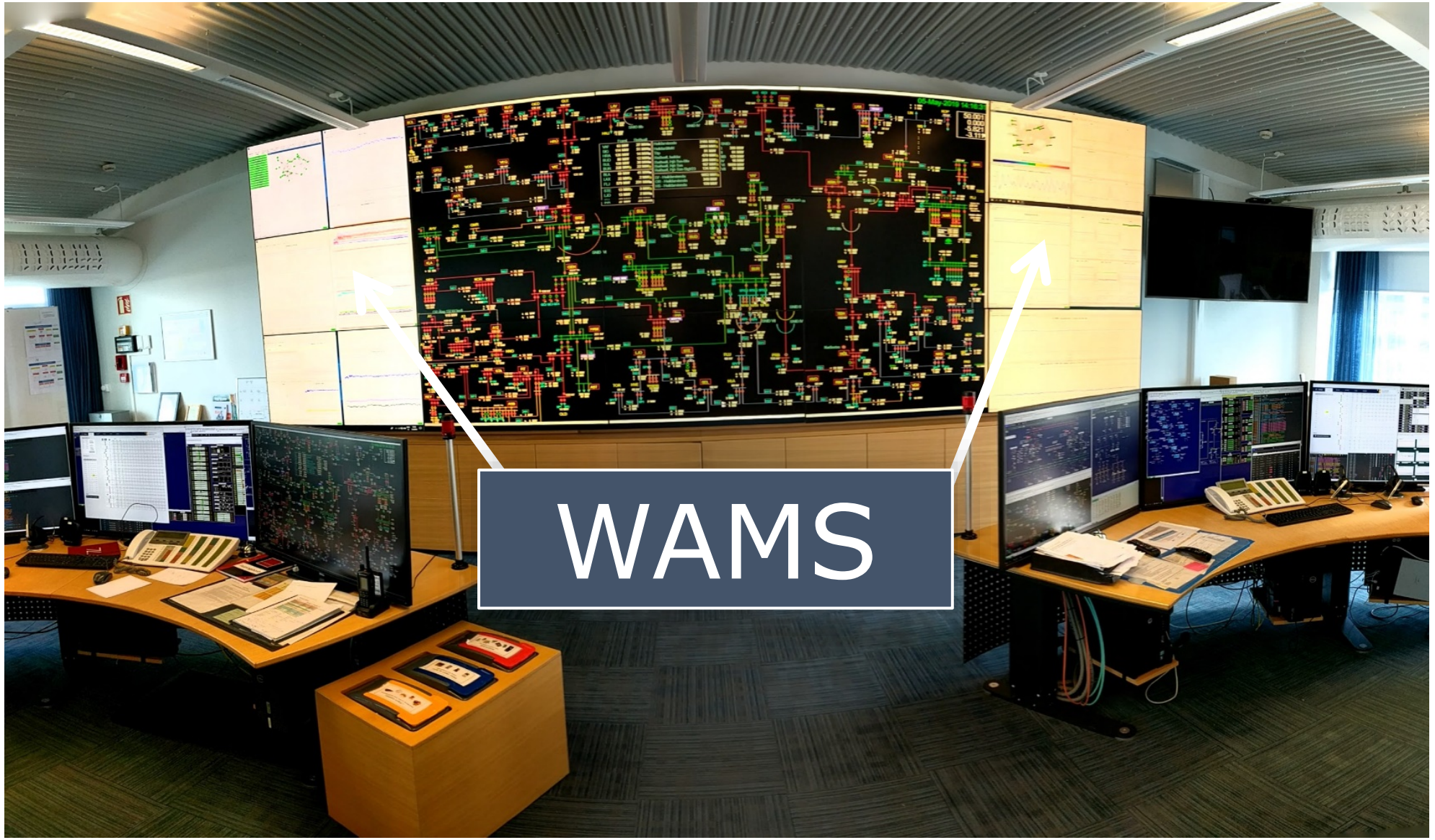
**Q: Why do operators need WAMS, isn´t it too much information?**

**A: I prefer to drive my car in the dark with the headlights turned on**

*Ragnar Stefánsson– Operator at Landsnet*

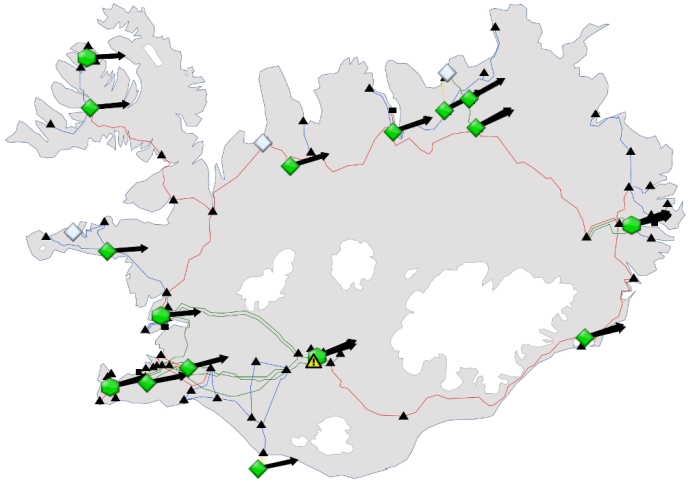
# Landsnet's Control Room – without headlights

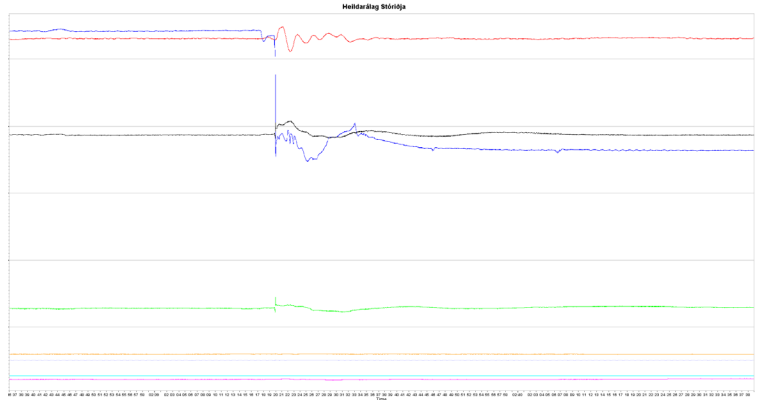
# Landsnet's Control Room – with headlights

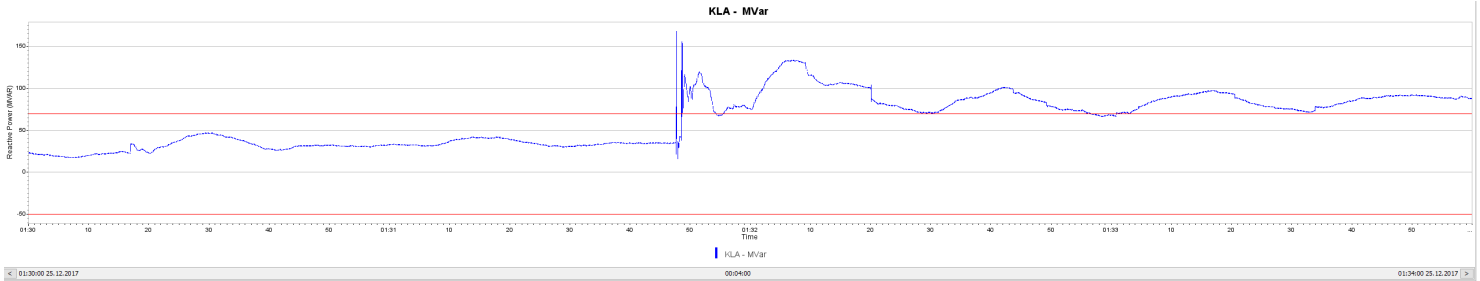


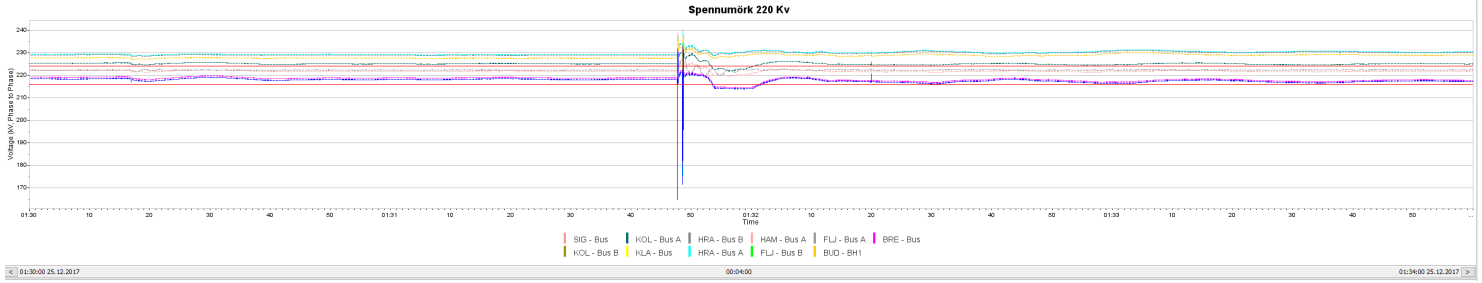
# WAMS

**Real-time Monitoring**





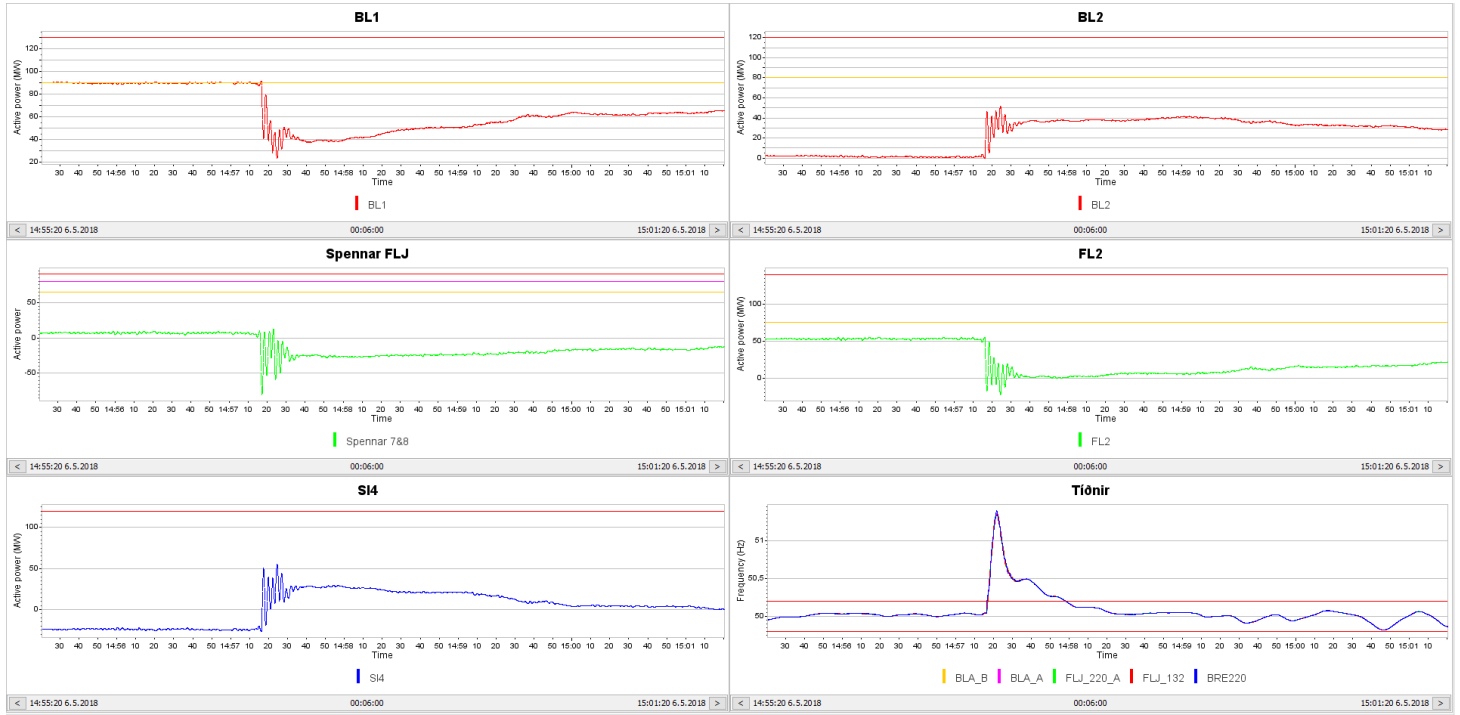



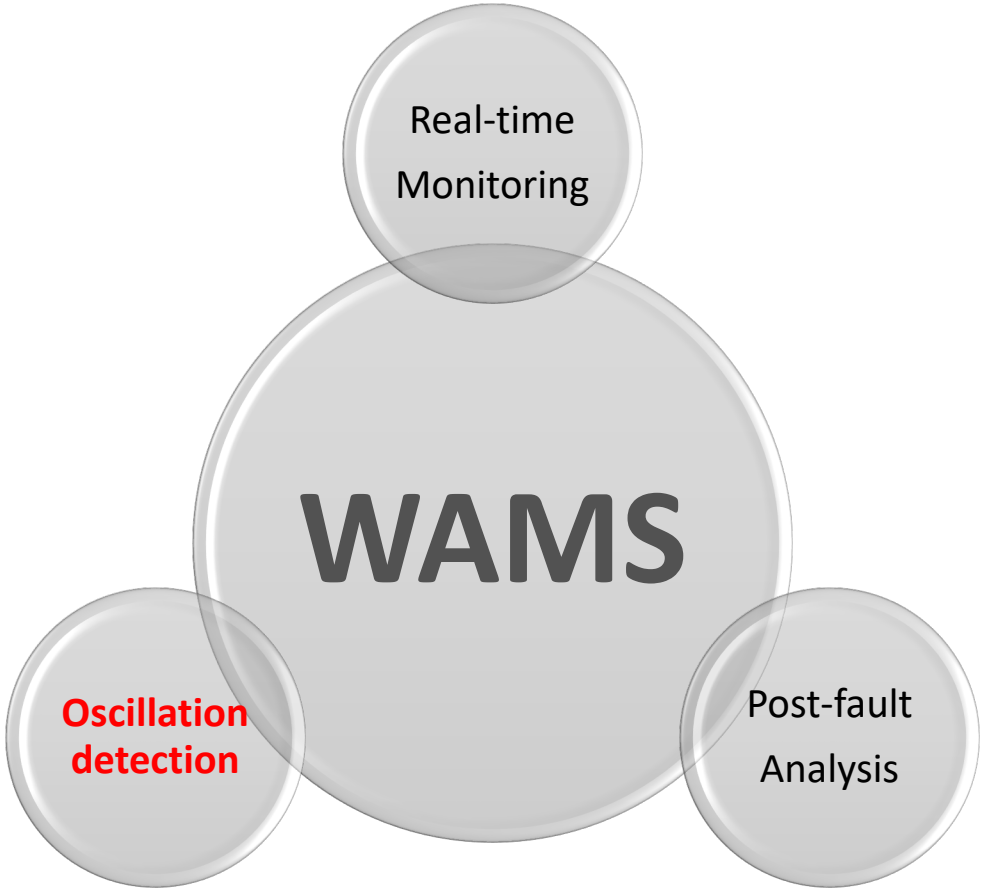



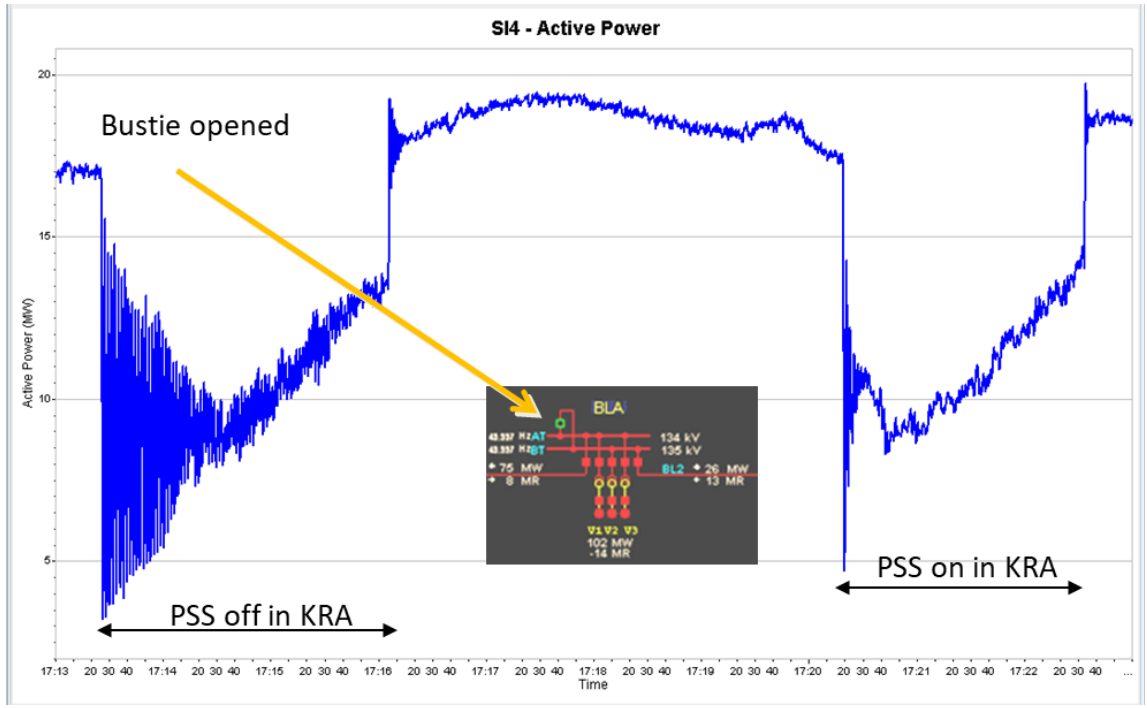
Real-time Monitoring

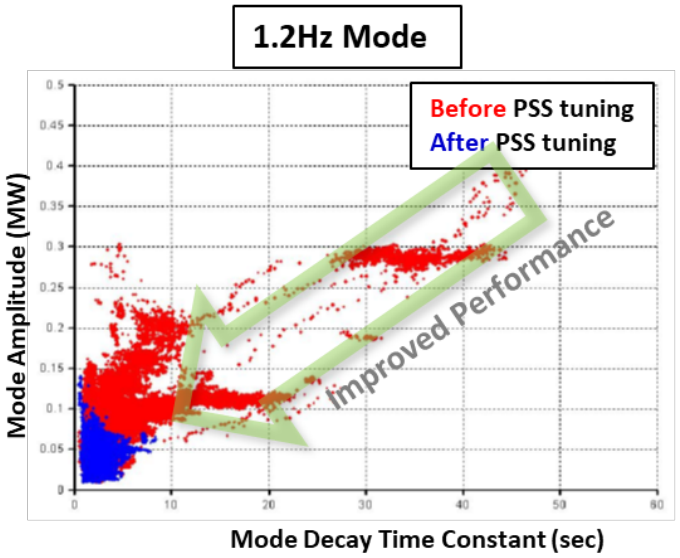
# WAMS

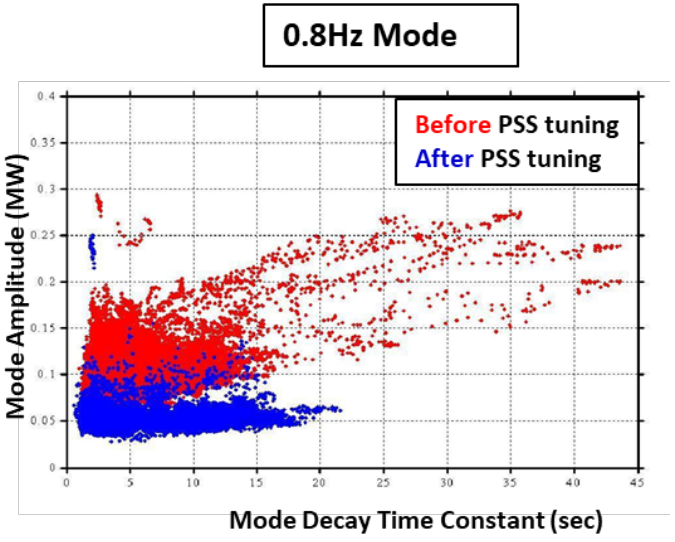
**Post-fault Analysis**

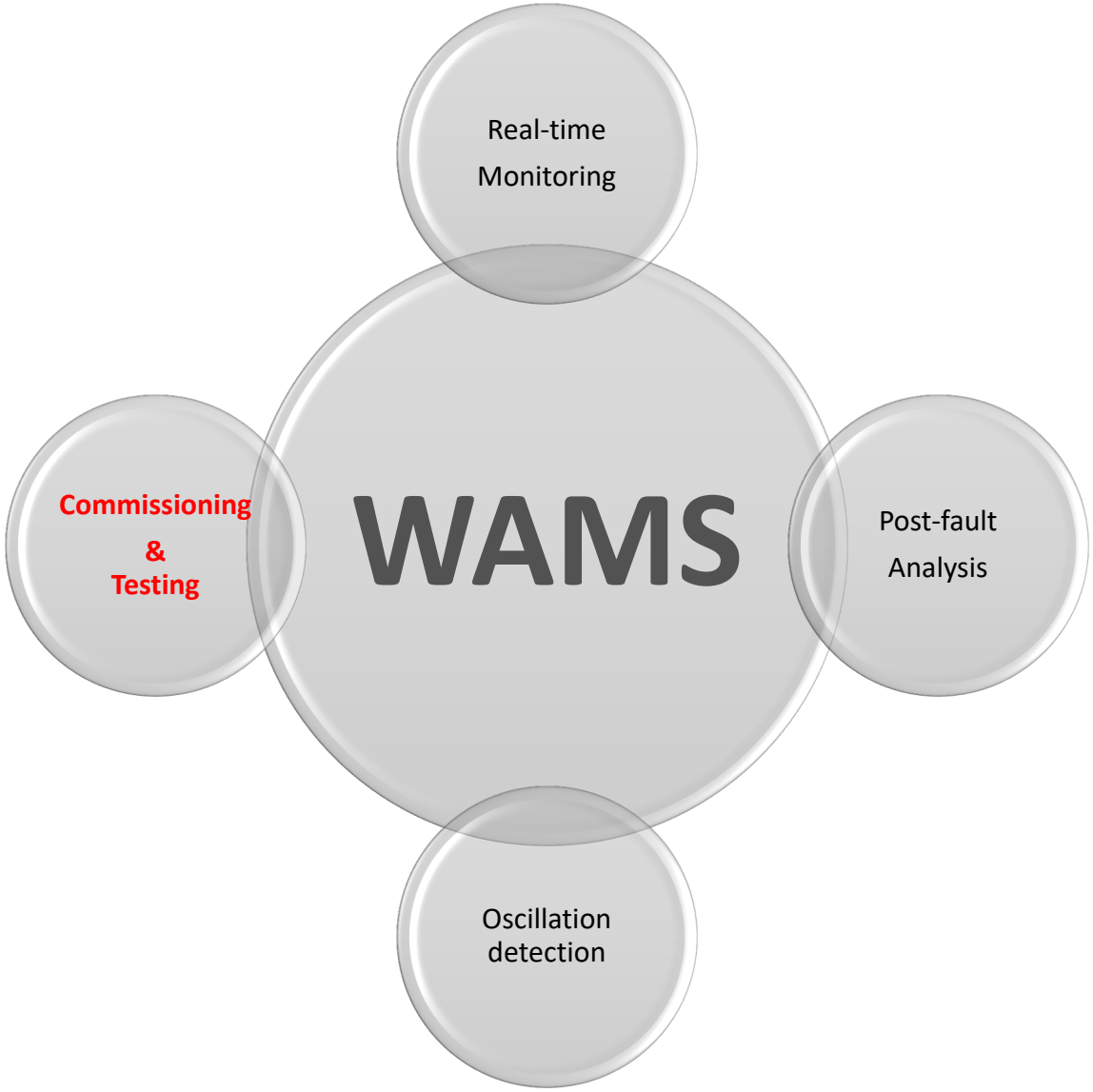


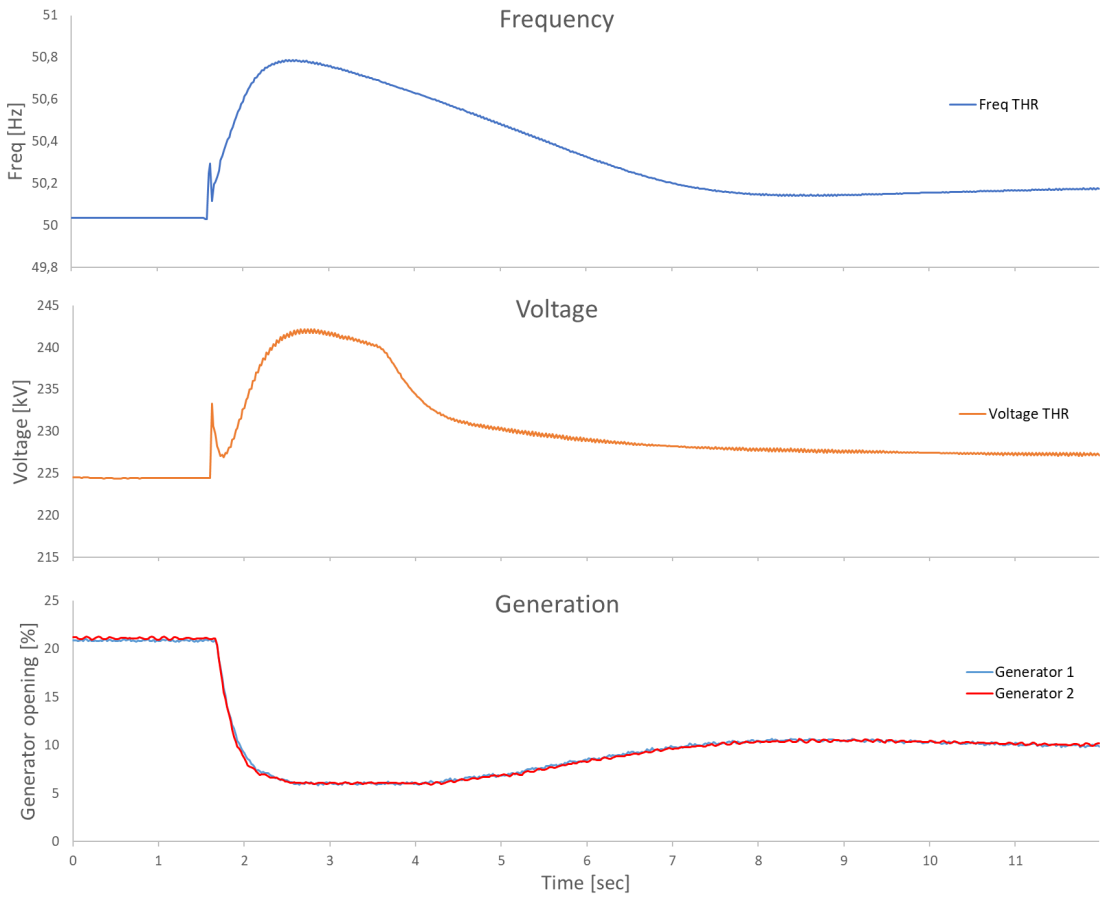

Real-time
Monitoring
WAMS
Oscillation
detection
Post-fault
Analysis

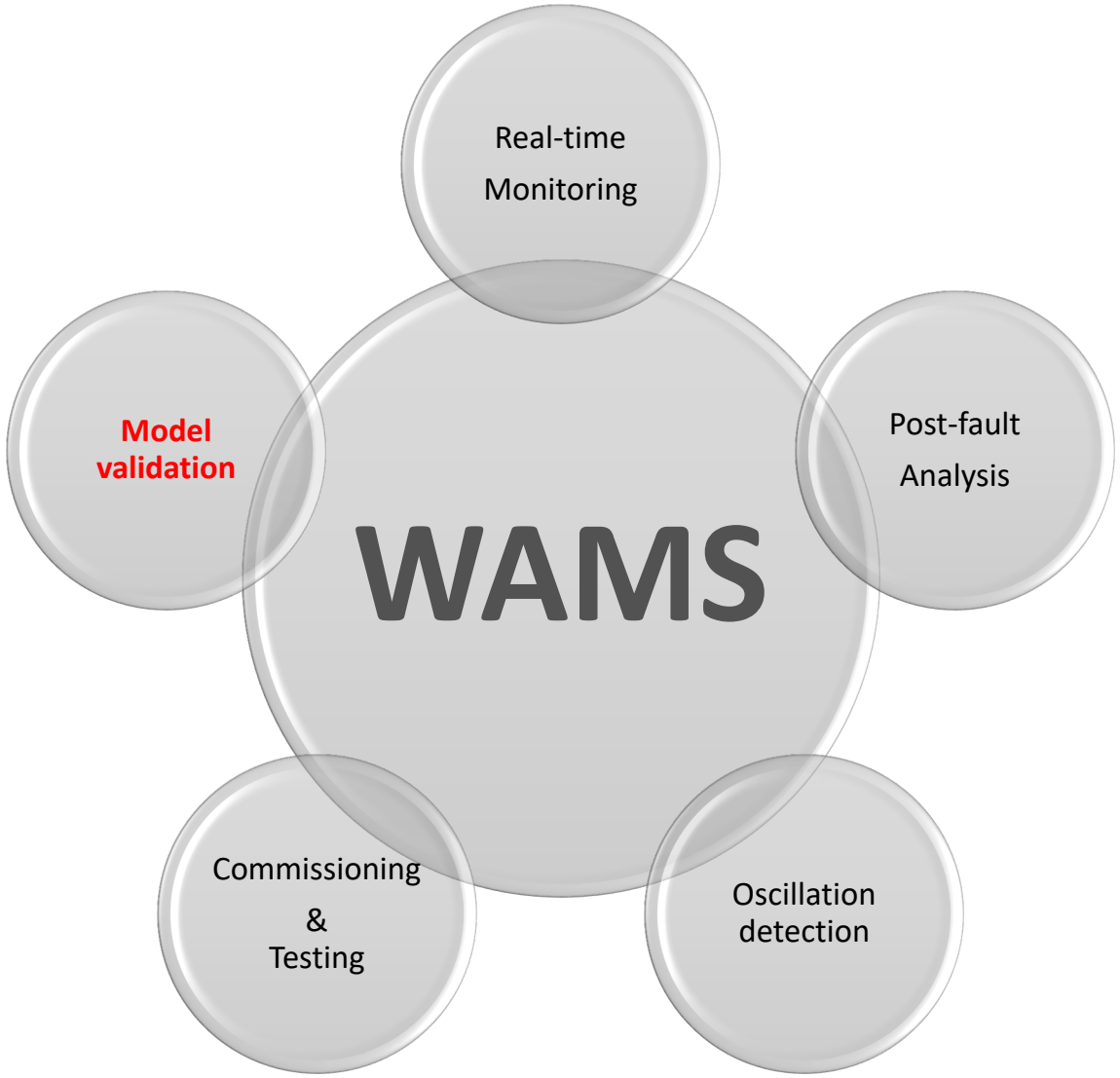

SI4 - Active Power
Bustie opened
PSS off in KRA
PSS on in KRA
Active Power (MW)
Time

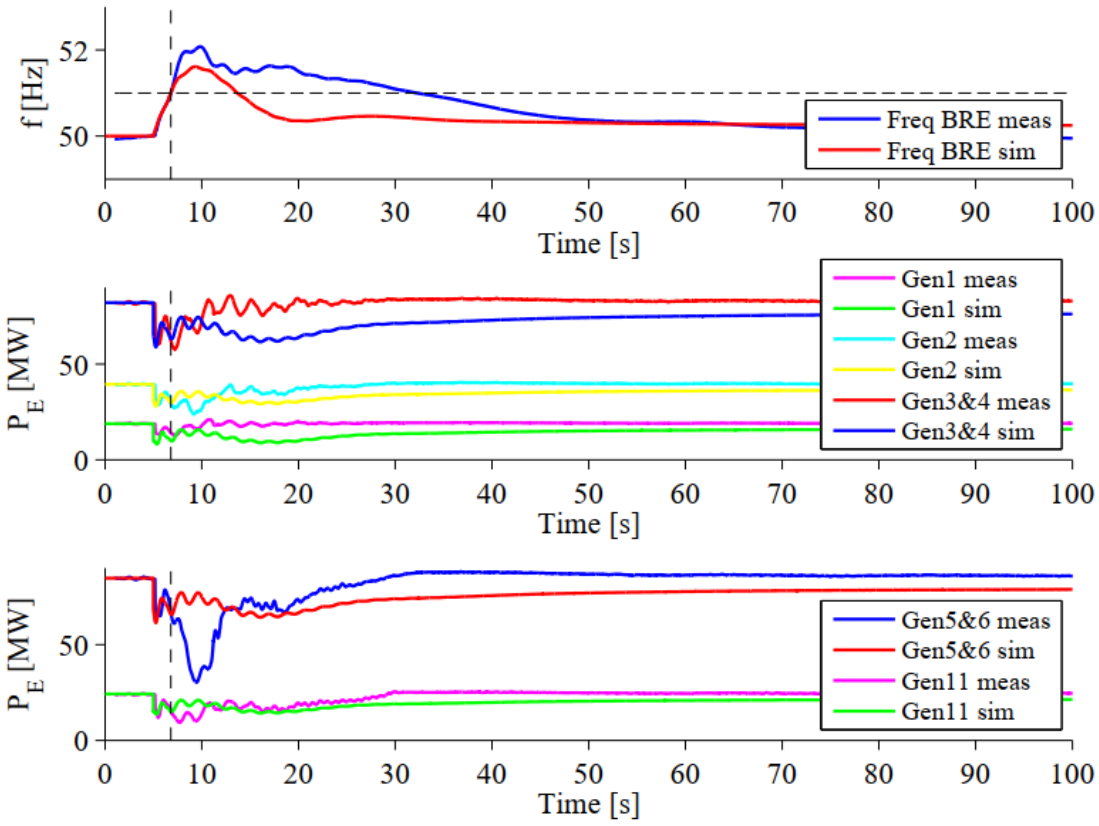

1.2Hz Mode
Before PSS tuning
After PSS tuning
Improved Performance
Mode Amplitude (MW)
Mode Decay Time Constant (sec)

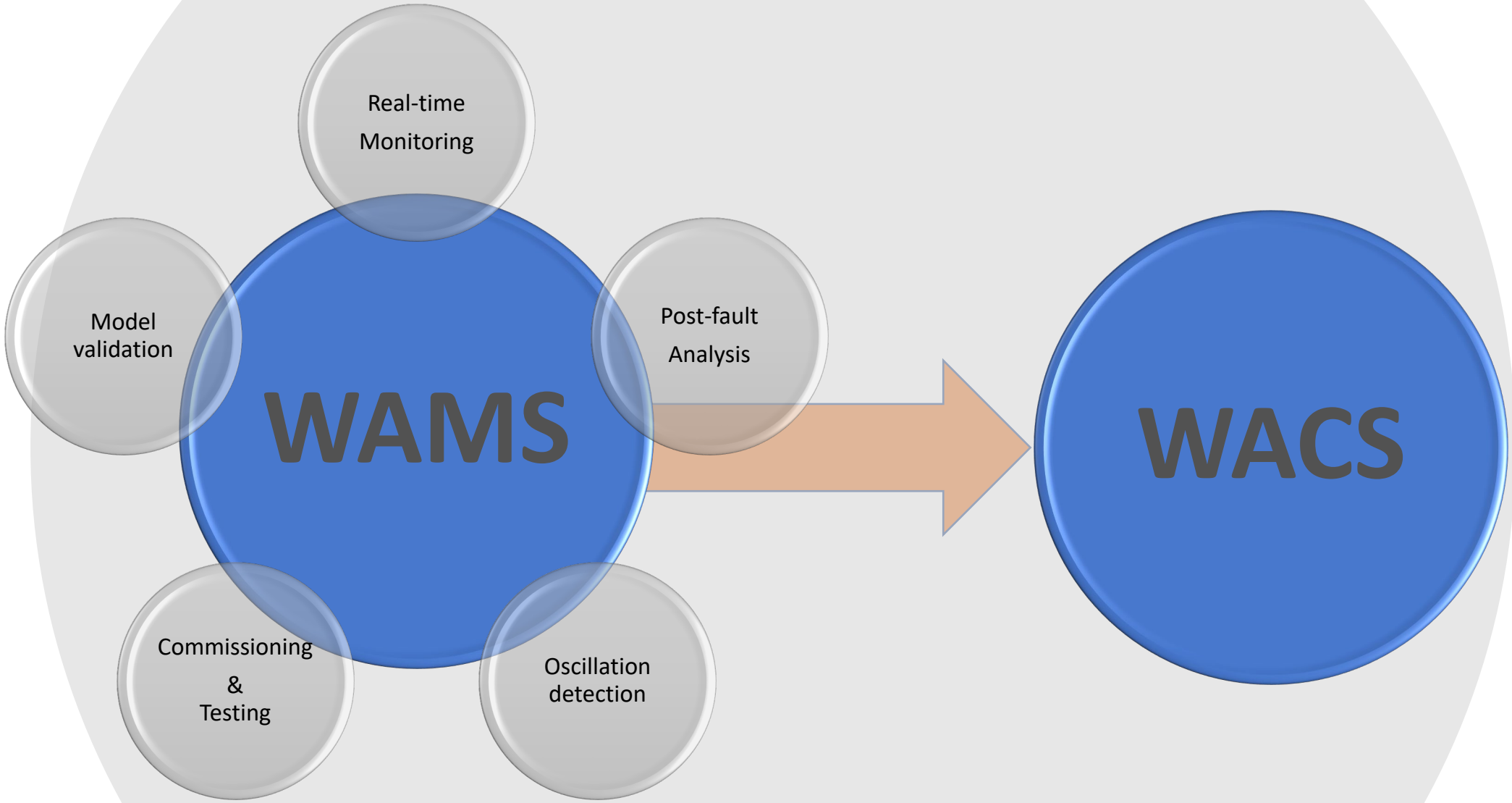

0.8Hz Mode
Before PSS tuning
After PSS tuning
Mode Amplitude (MW)
Mode Decay Time Constant (sec)


Real-time
Monitoring
Commissioning
&
Testing
WAMS
Post-fault
Analysis
Oscillation
detection


Frequency
Freq [Hz]
51
50,8
50,6
50,4
50,2
50
49,8
Freq THR
Voltage
Voltage [kV]
245
240
235
230
225
220
215
Voltage THR
Generation
Generator opening [%]
25
20
15
10
5
0
Generator 1
Generator 2
0
1
2
3
4
5
6
7
8
9
10
11
Time [sec]


Real-time
Monitoring
Model
validation
WAMS
Post-fault
Analysis
Commissioning
&
Testing
Oscillation
detection


f [Hz]
52
50
Freq BRE meas
Freq BRE sim
0 10 20 30 40 50 60 70 80 90 100
Time [s]
P_E [MW]
50
0
Gen1 meas
Gen1 sim
Gen2 meas
Gen2 sim
Gen3&4 meas
Gen3&4 sim
0 10 20 30 40 50 60 70 80 90 100
Time [s]
P_E [MW]
50
0
Gen5&6 meas
Gen5&6 sim
Gen11 meas
Gen11 sim
0 10 20 30 40 50 60 70 80 90 100
Time [s]


Real-time
Monitoring
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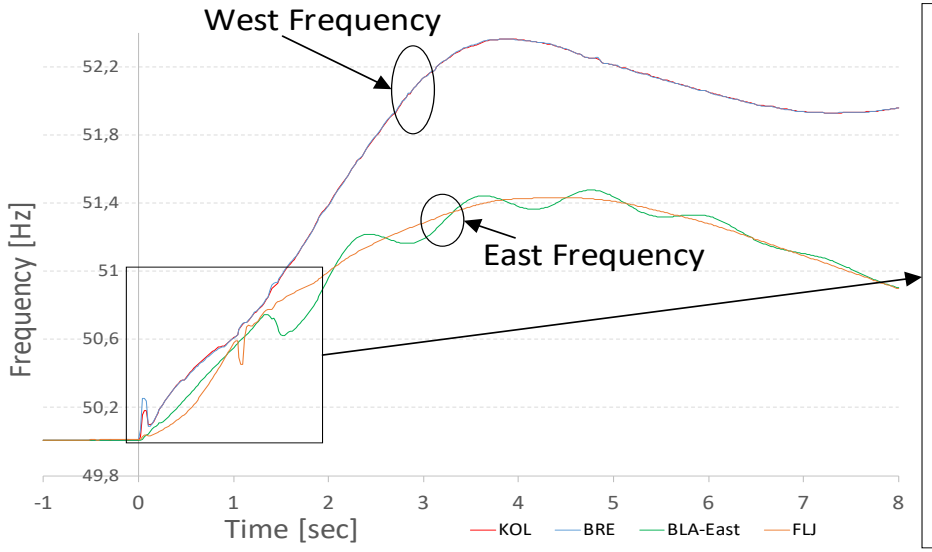
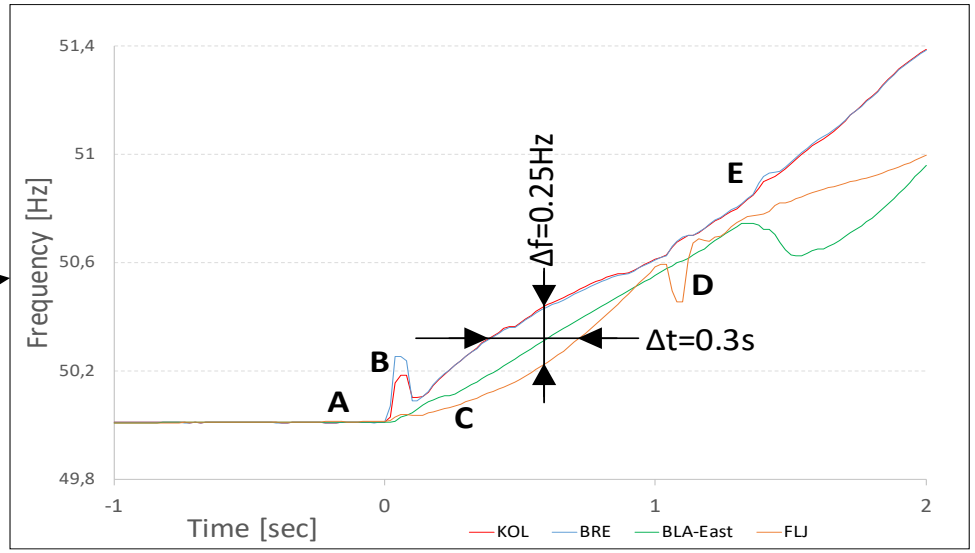
Oscillation
detection
WACS

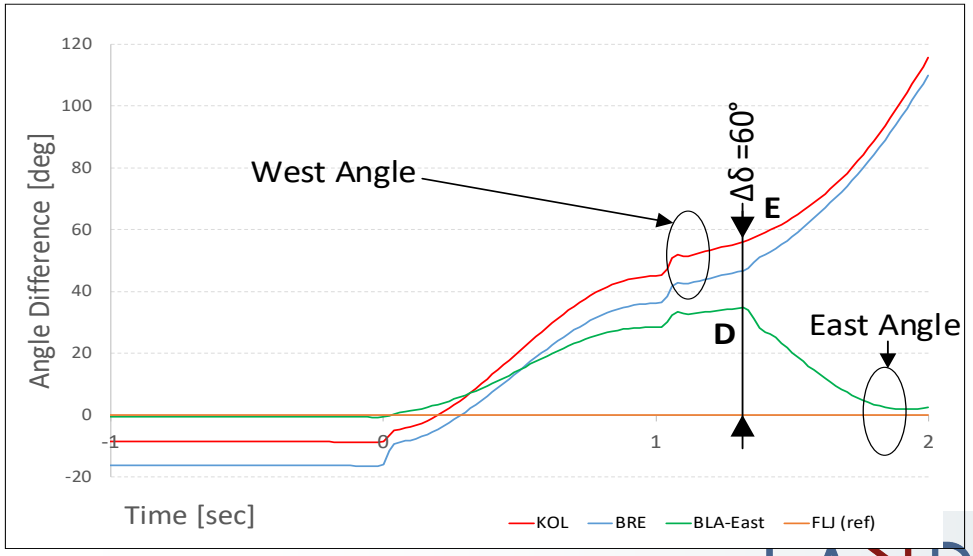
# Effect of Sparse Centres of Inertia

- Iceland shows frequency & angle divergence between centres of inertia

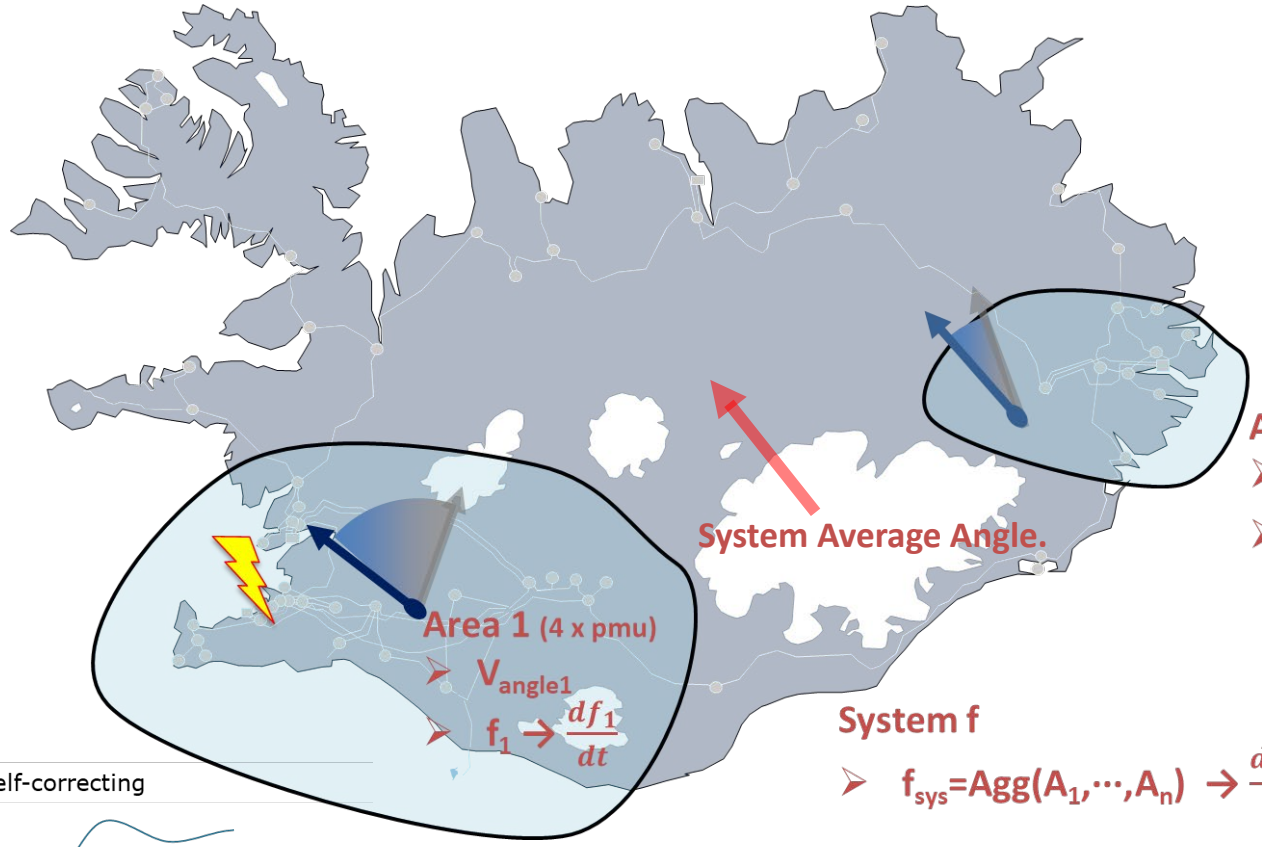



| | | |
|---|---|---|
| **A** | T=0s | Industrial load #1 reduction (first stage) |
| **B** | T=0.2s | Industrial load #1 reduction (second stage) |
| **C** | T=0.36s | Industrial load #1 trip |
| **D** | T=1.1s | Area angles separated by 60°, result in high E-W power. One route opens by special protection |
| **E** | T=1.2s | Areas accelerate away from each other; synchronism is lost and system islands |

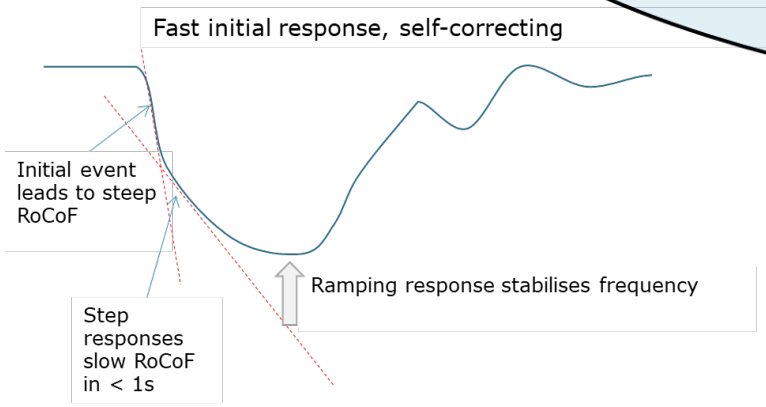


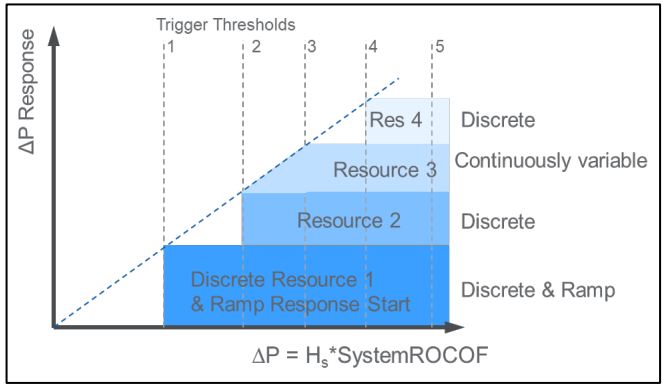
# General Method for Locational Fast Response




System f

- $f_{sys}=Agg(A_1,\cdots,A_n) \rightarrow \frac{df_{sys}}{dt}$

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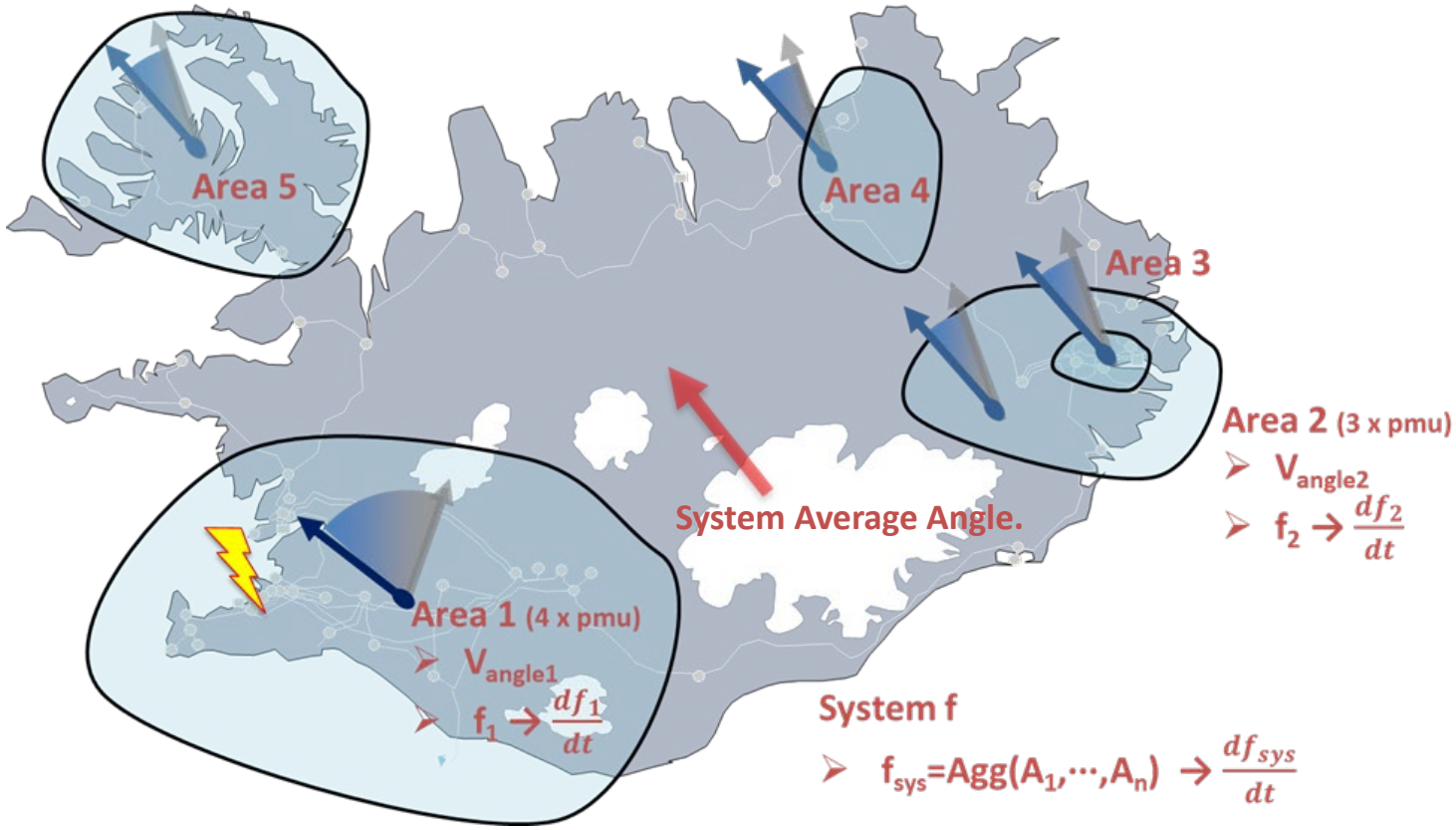


- **Fast**
- **Locational**
- **Proportional to disturbance**

- **Response Driven**
- **Event Driven**

MIGRATE

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# Smart-Grid Projects


Vestfirðir Microgrid

2015

THR Microgrid / Geoth. control

2018-2021*


Smelter Load Control

2015


Smelter
Load Control & Microgrid

2016

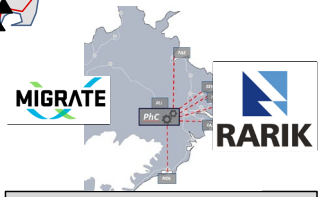

Hydro Fast Ramp

2017-2018

Lines & cables
220 kV
132 kV
66 kV
33 kV


Smelter Load Control

2017-2018



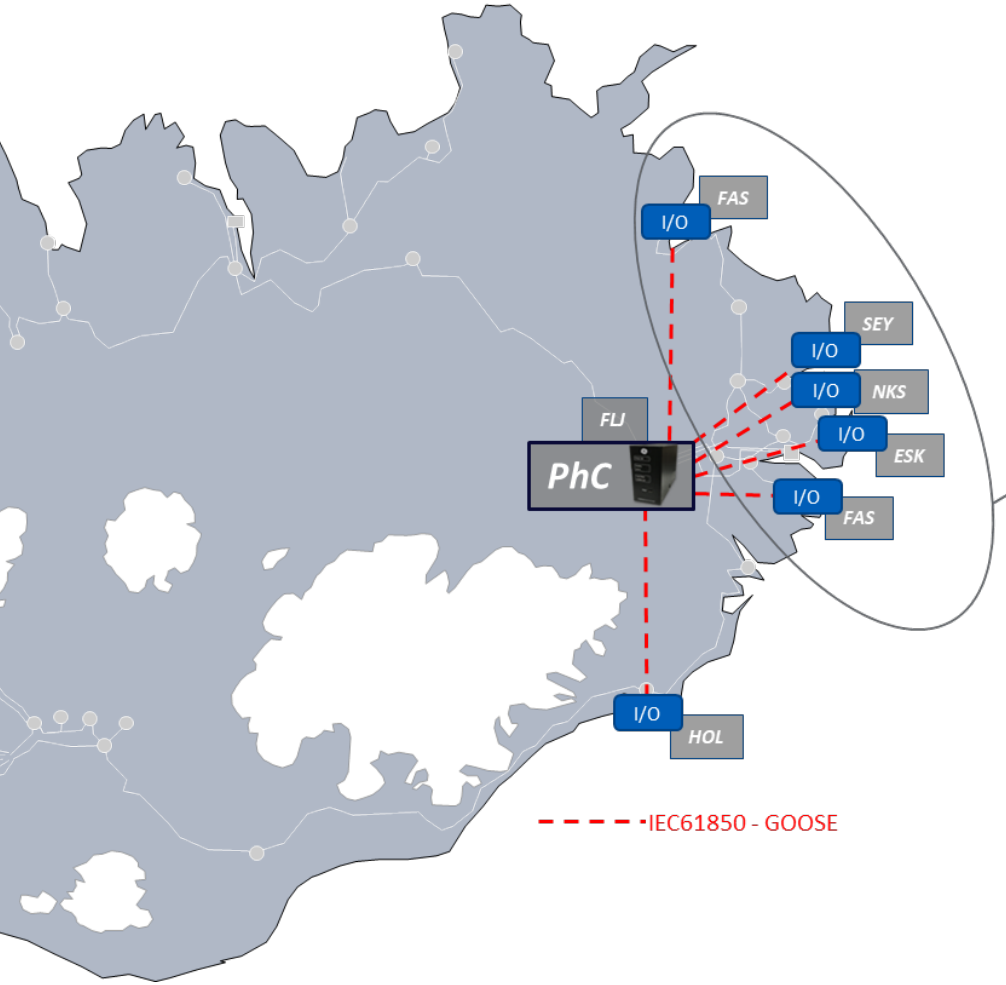

Fish facories Load Control

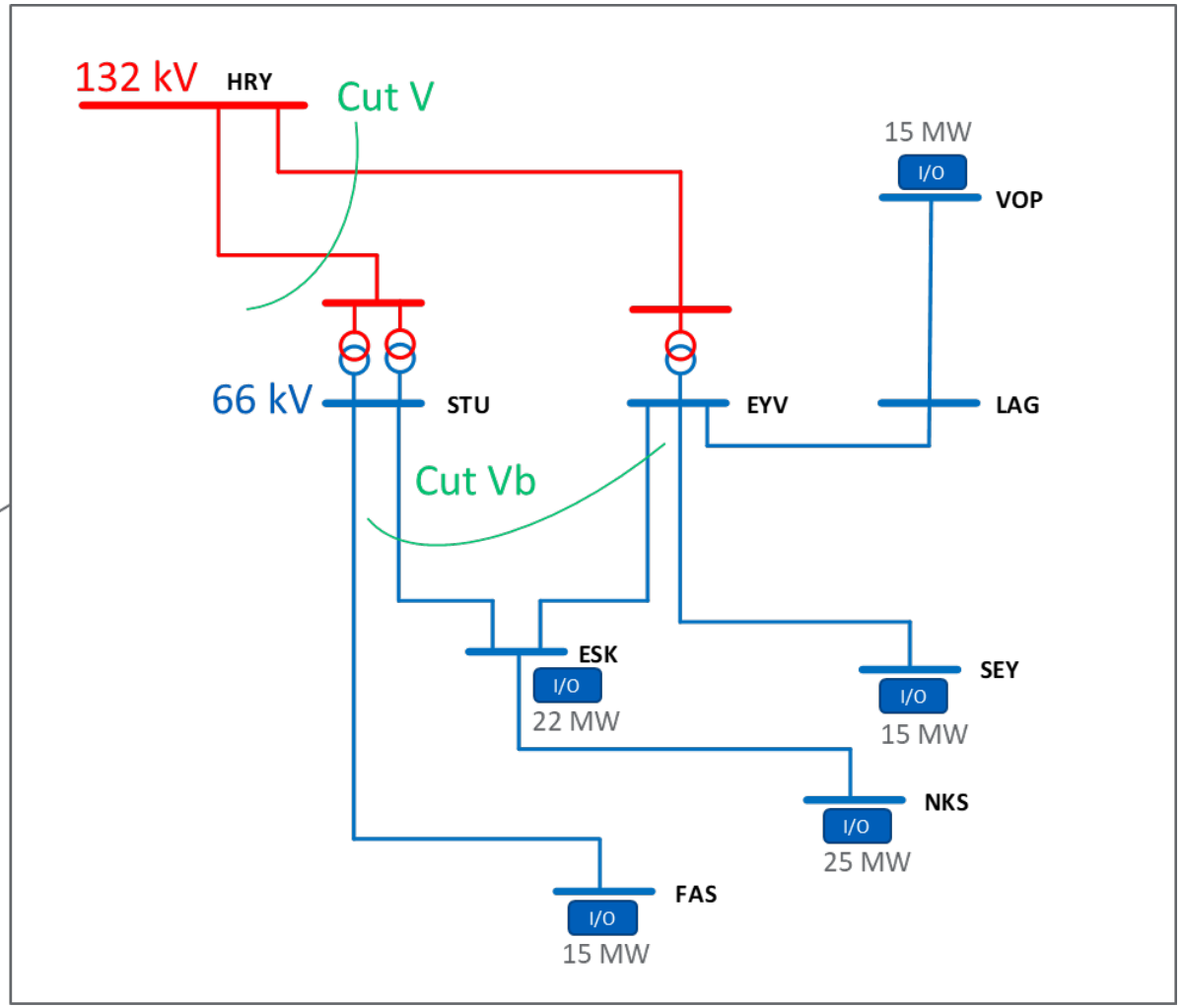
2014, 2017-2018


Reykjanes Microgrid
Load control and Geoth. control

2018-2021

# Implementation

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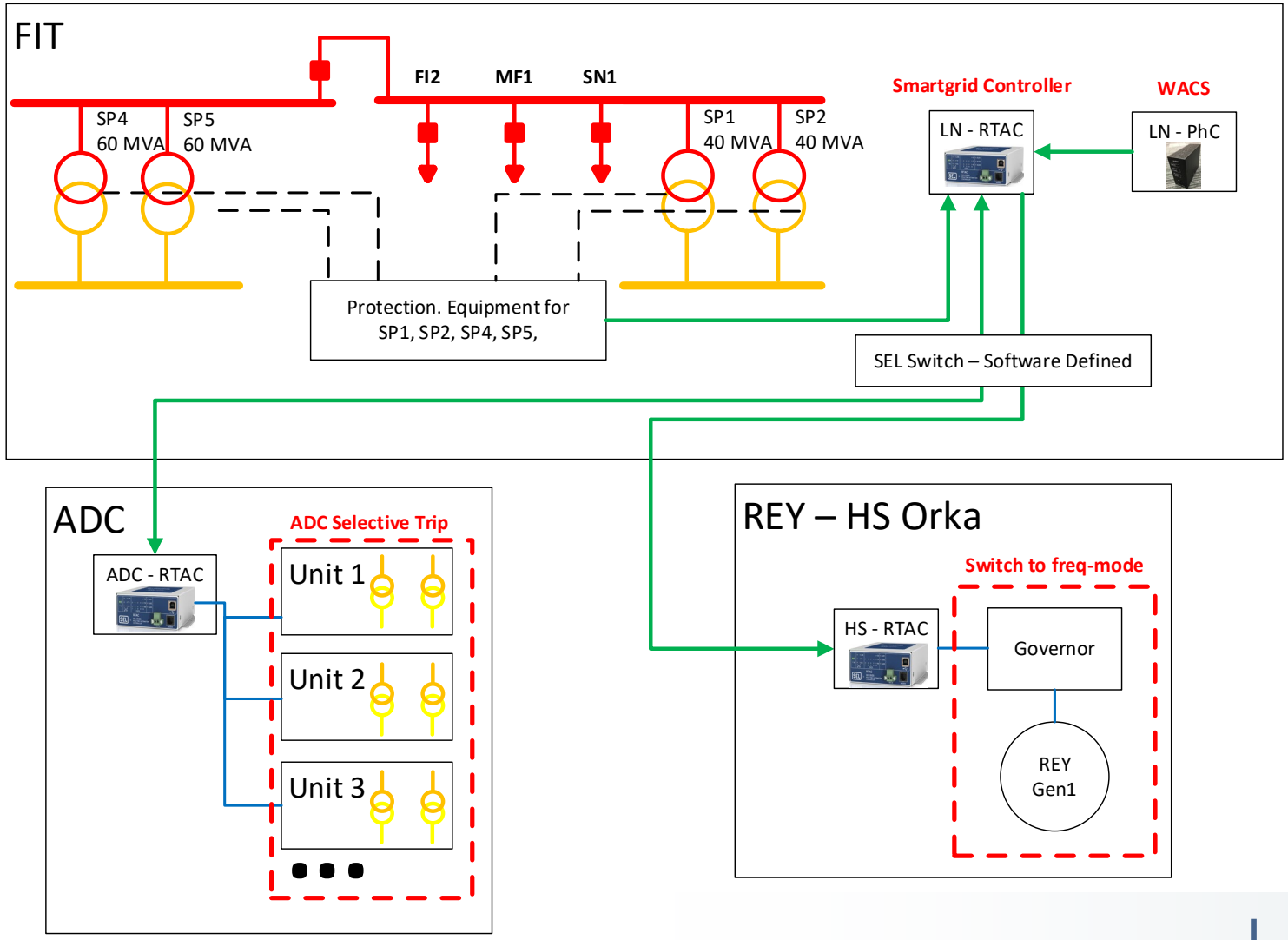
# Implementation

## Smartgrid Project in Reykjanes – Load Shed Control and Generator Governor Mode by using GOOSE [IEC 61850]

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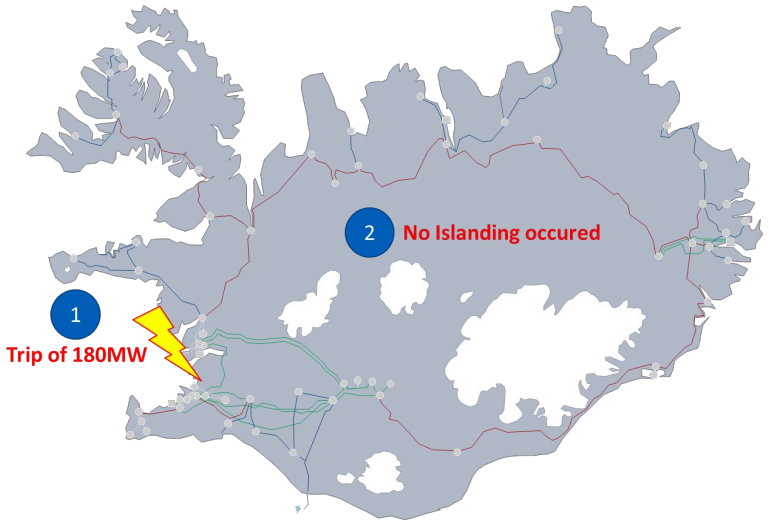
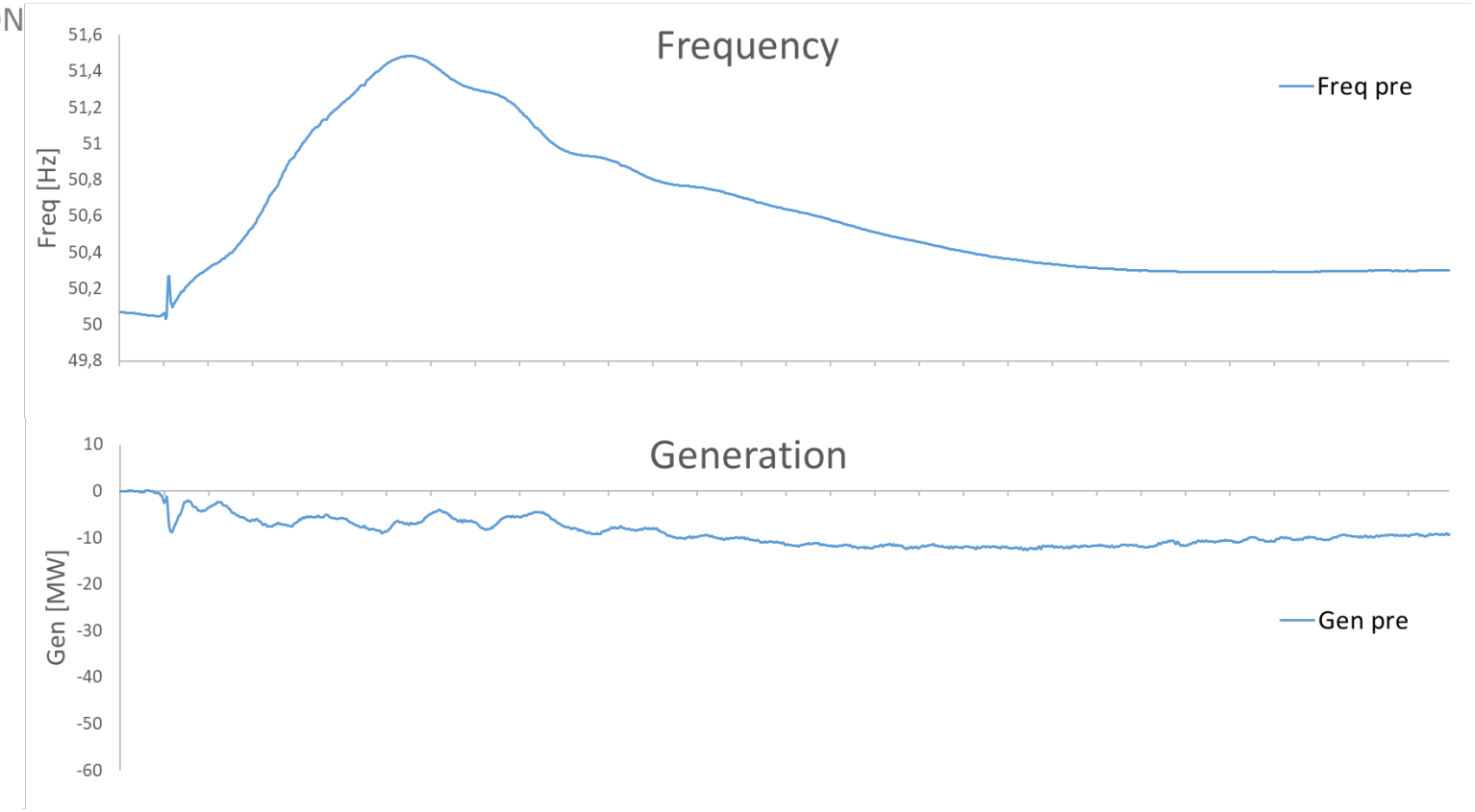
# REAL SYSTEM RESPONSES

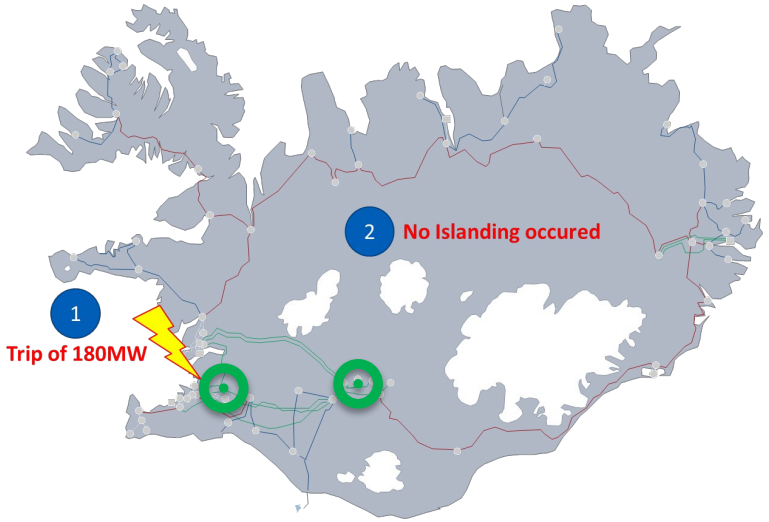
LOAD LOSS EVENT BEFORE WACS IMPLEMENTATION



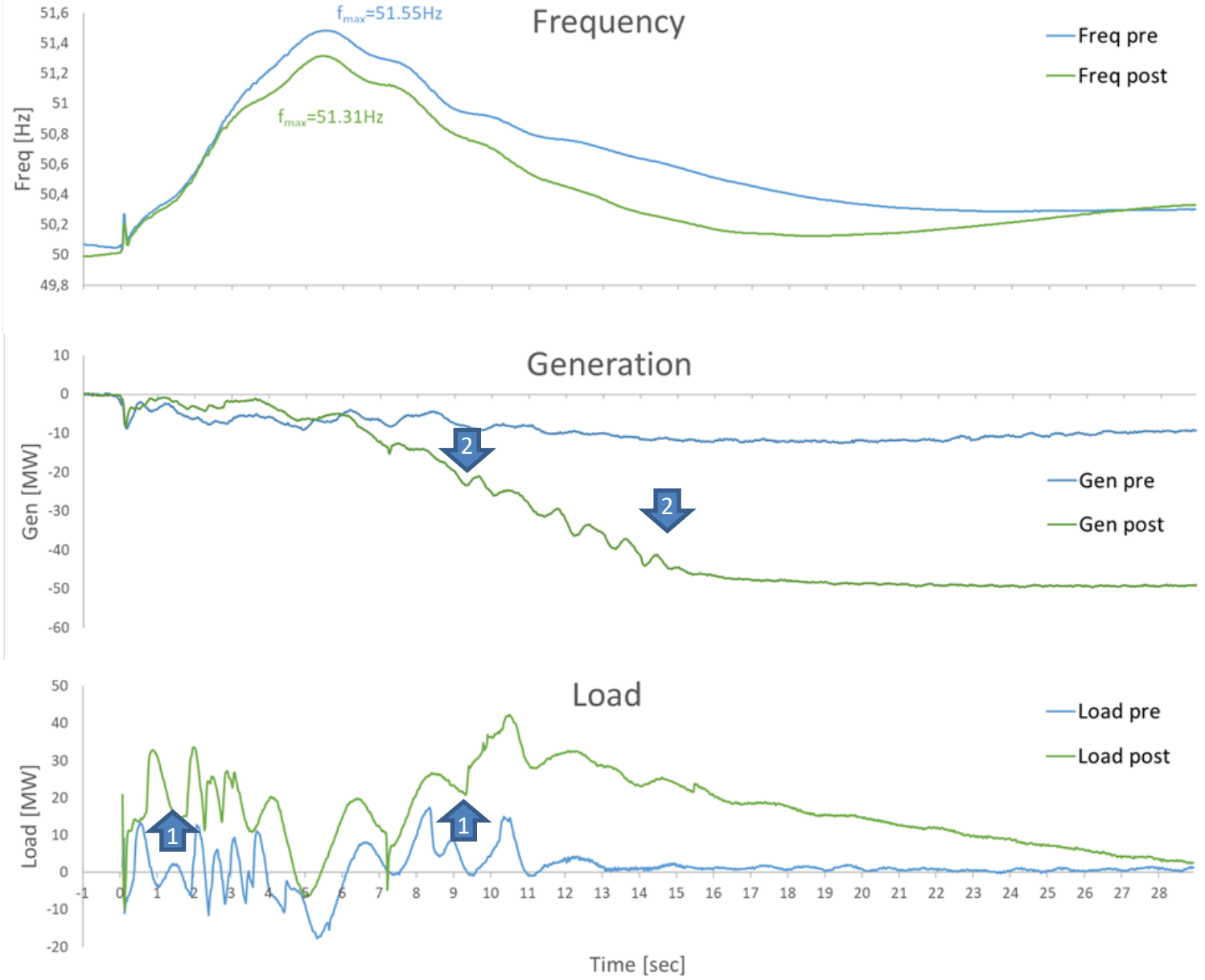
# REAL SYSTEM RESPONSES

LOAD LOSS EVENT AFTER WACS IMPLEMENTATION



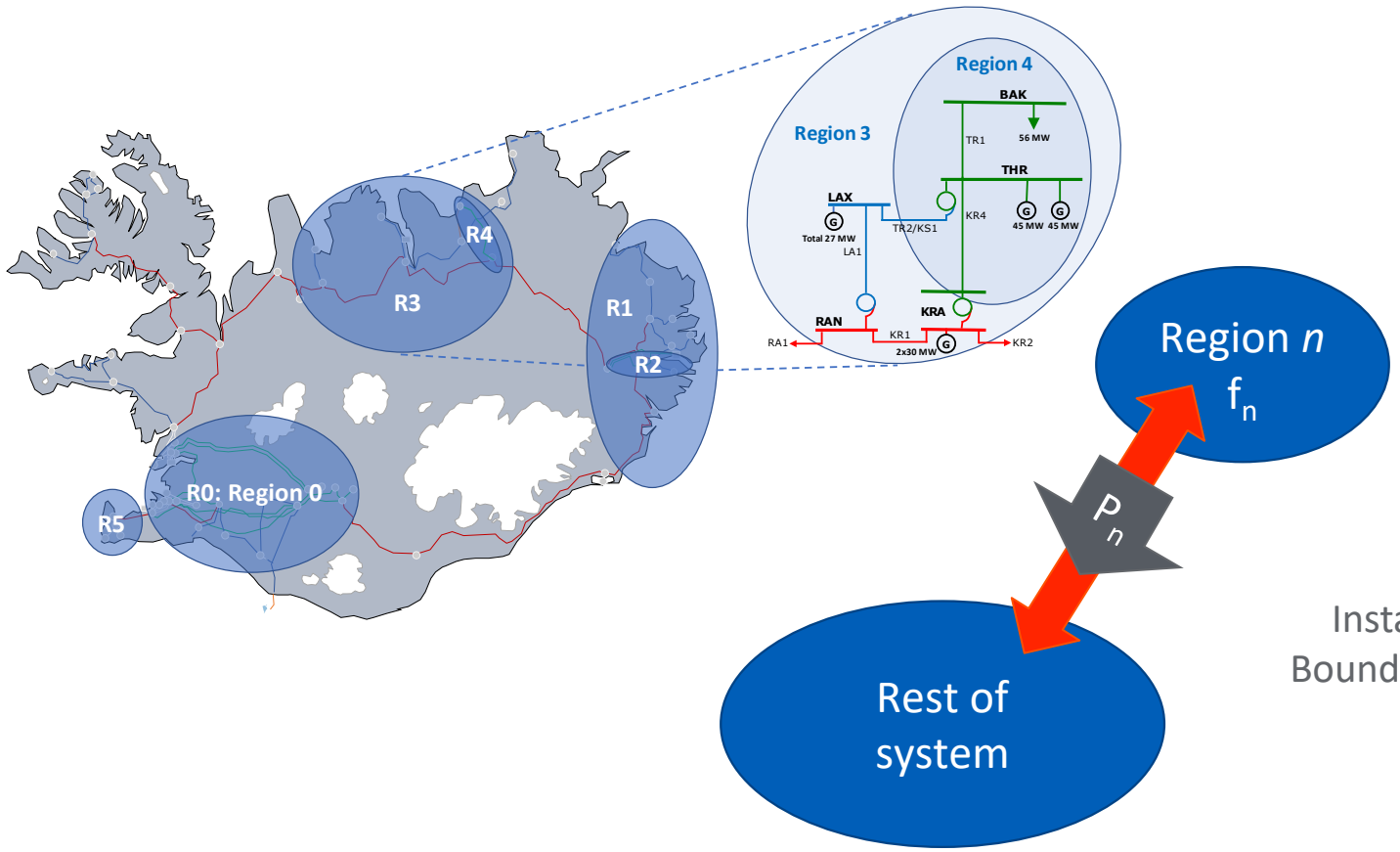

1 *Load response in <0.5s, reduces frequency peak.*

2 *Hydro fast ramp start at 3.5s, replaces fast temporary load response. Rate & volume greater than primary control*



# Latest Development in Wide Area Control

## for locational frequency response and regional re-balancing

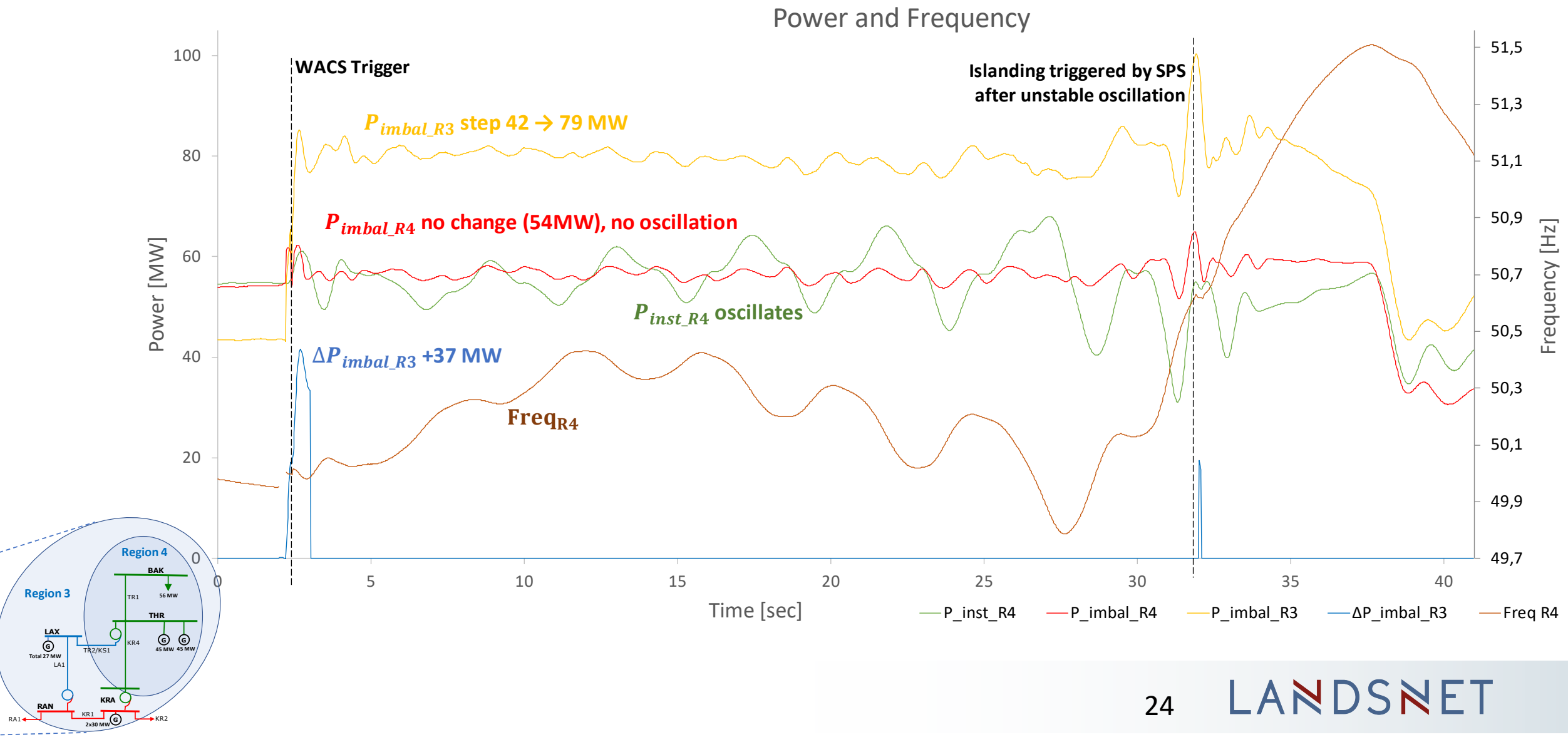



**Goal:** Quickly find the imbalance of load and generation for a region in the presence of dynamic power swings, so that we can re-balance the area.

$$P_n = P_{Imbal} - H_n . ROCOF_n$$

- $P_n$: Instantaneous Boundary Power
- $P_{Imbal}$: **Region *n* Power Imbalance** — not directly measurable
- $H_n$: **Effective Area Inertia**
- $ROCOF_n$: Region *n* Ctr of Inertia ROCOF

# Example of Region 3 load loss and oscillations



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# Conclusion

- WACS have improved the system performance during disturbances:
  - The system operators experience less severe disturbances, improving system security
  - The generator operator experiences fewer plant trips and large frequency excursions which extends the lifetime of the machines
  - The load customers in the region experience fewer and shorter interruptions and better power quality
- There are still many promising WACS project proposals, more capacity of regulating units in south west, harnessing the fast response of geothermal units, regulating options with datacenters and wide-area-damping.
- Fast Frequency Response (FFR) ancillary service is in development.
- Digital Substation projects increase the demand of fast and reliable communication between substations. Which opens the option for routable GOOSE,SV [IEC TR 61850-90-5] for enhanced protection and control.


Thank you for your attention
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