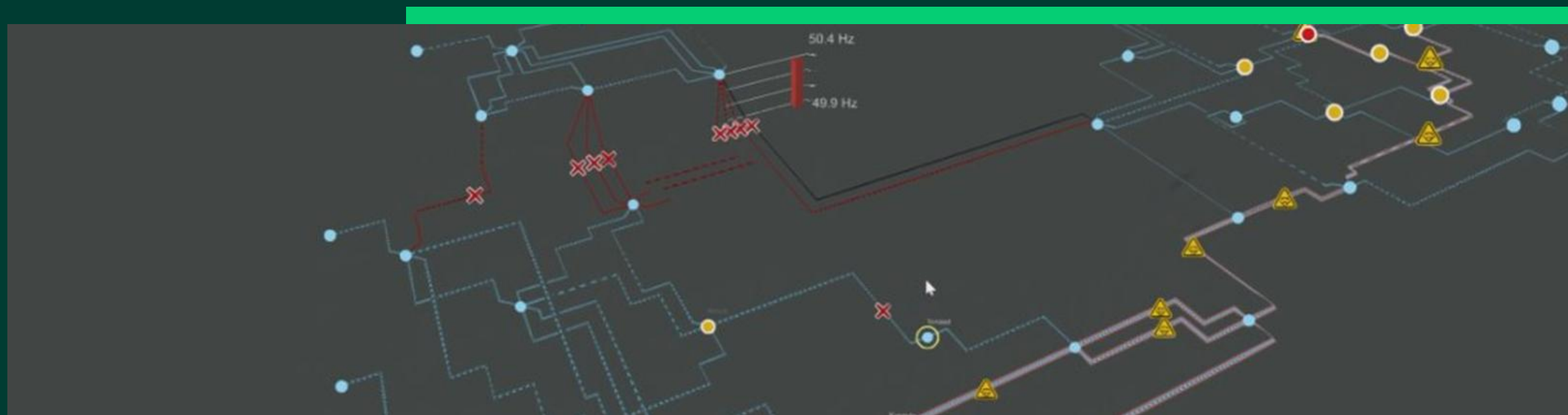


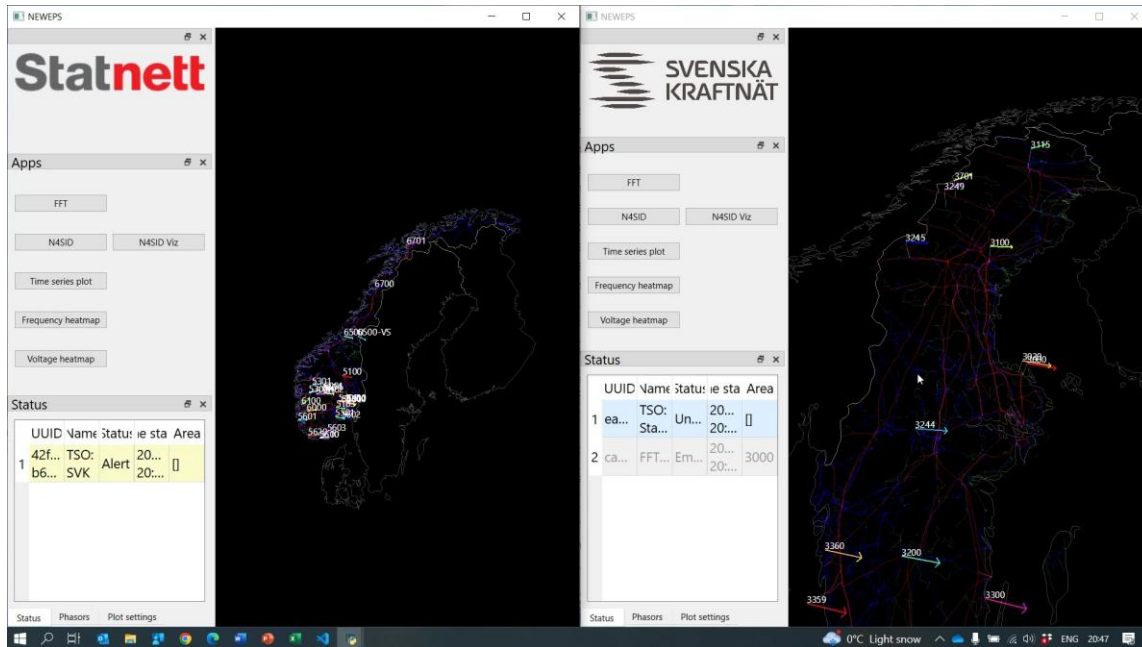
Statnett

– Statnett R&D WAMPAC

power- Wide Area Monitoring Protection  
(p-SWAMP)



# Motivation



[NEWEPS - Nordic Early Warning Early Prevention system](#)

[NEWEPS Demo C - Part 2, Voltage Stability Monitoring on Vimeo](#)

[What's Happening in Spain? The 2025 Blackout and the Global Threat Ahead!](#)

[28 April Blackout](#)

# Statnett SF The Norwegian Transmission System Operator (TSO)

Owned by the Norwegian State through the Ministry of Energy

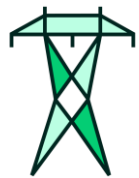
Owns and operates the national high voltage transmission grid in Norway, i.e. the electricity highways.

Operation of the Nordic power grid is a collaboration between Statnett in Norway , Svenska kraftnät in Sweden, Fingrid in Finland and Energinet in Denmark.

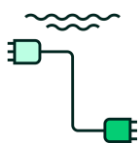
[Grid Map downloads](#)



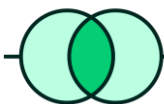
# Statnett SF



11 500 km high voltage lines



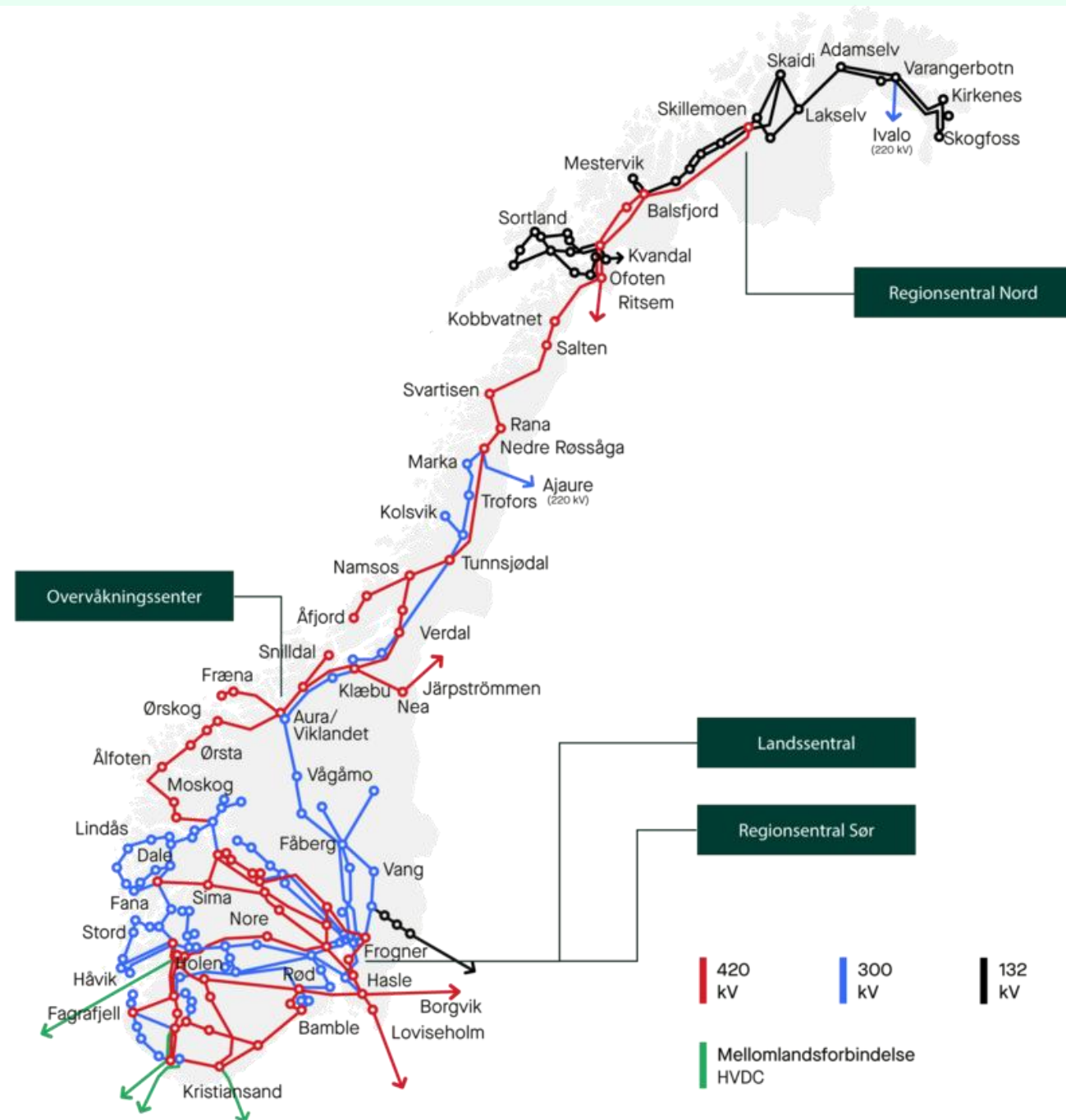
2 550 km subsea and underground cables



190 substations



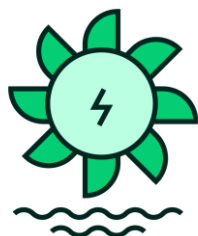
1 600 employees, 5 office locations  
(Oslo, Alta, Trondheim, Sunndalsøra  
and Sandnes)



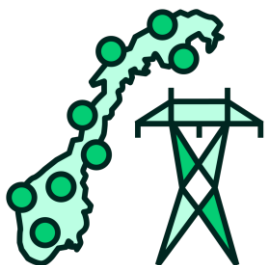
# The Norwegian power system



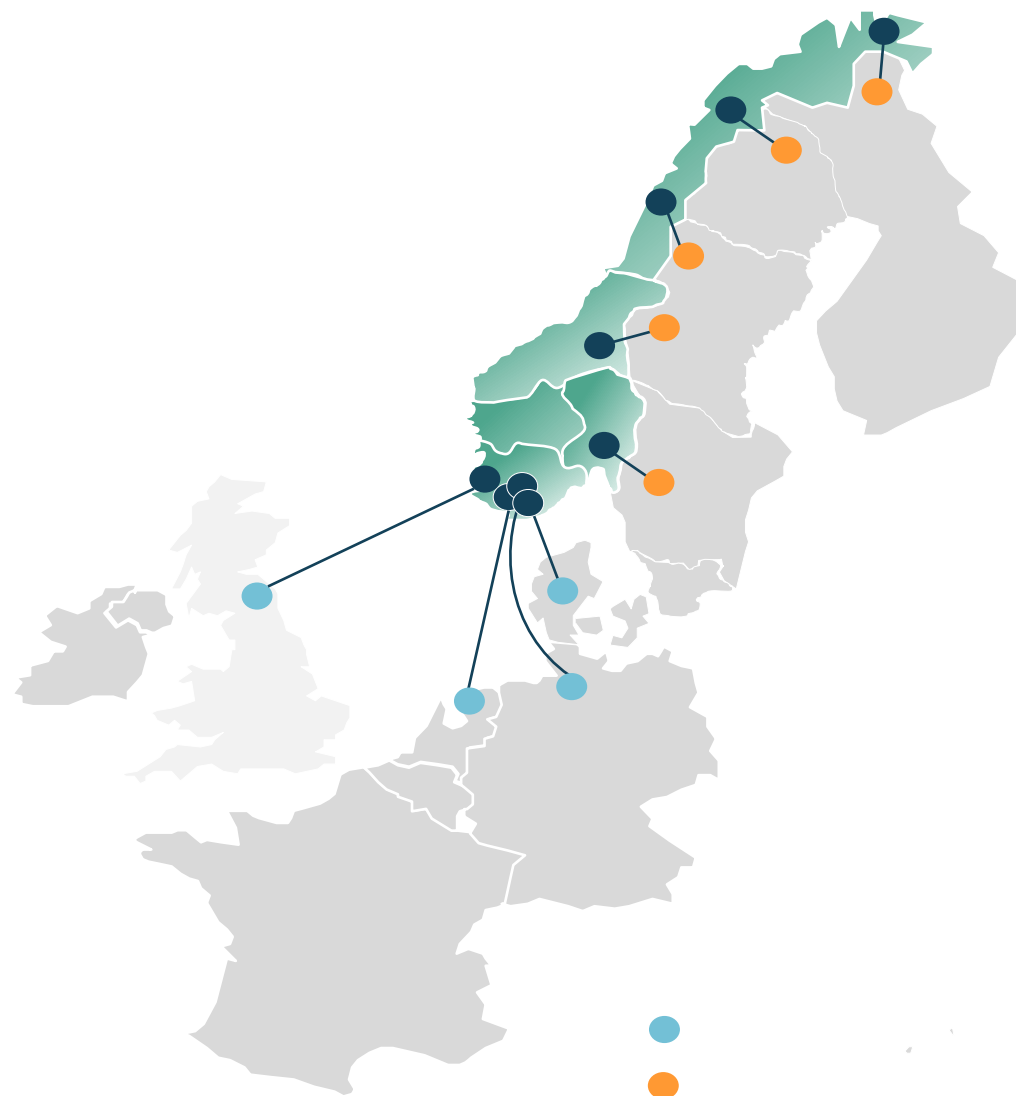
**Consumption**  
134 TWh



**Production**  
146 TWh



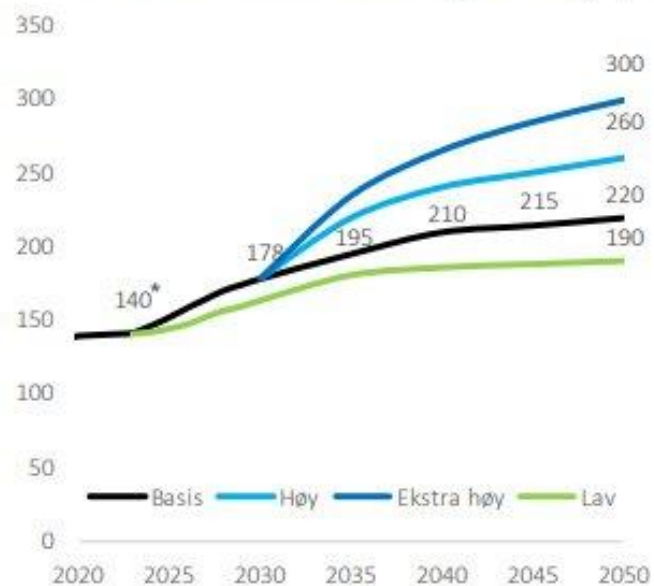
**Net exchange**  
12.5 TWh to:  
Sweden, Finland, Denmark, UK, Germany and  
Netherlands



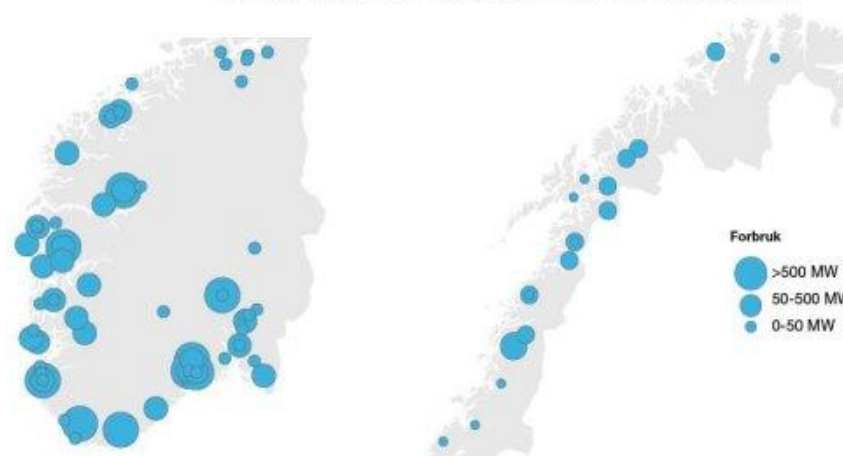
# Statnett – Challenges

Prognoses indicate higher consumption in Norway, connection of new larger consumers and more renewable production units (off-shore wind, on-shore wind and photovoltaic).

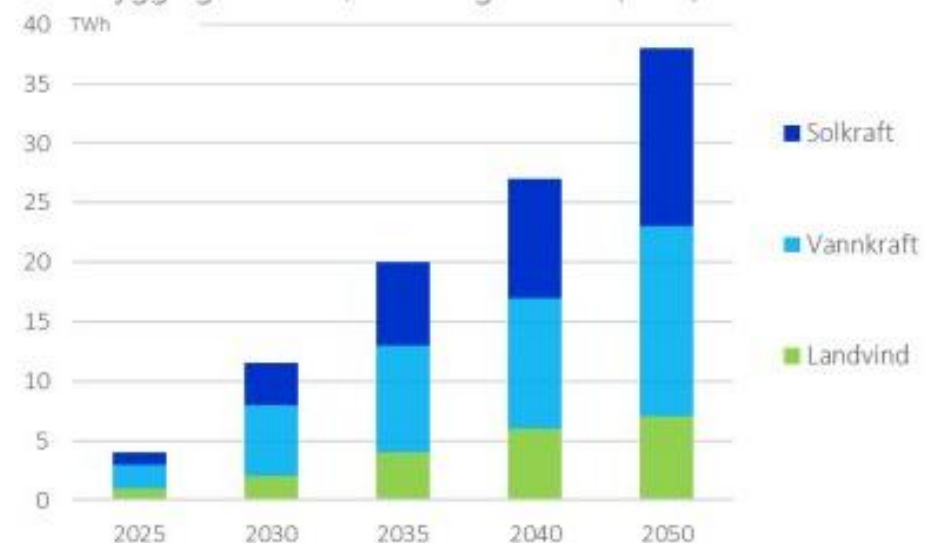
Ulike scenario for forbruksutviklingen i Norge (TWh)



Oversikt over lokalisering og volum på tilknytningssaker



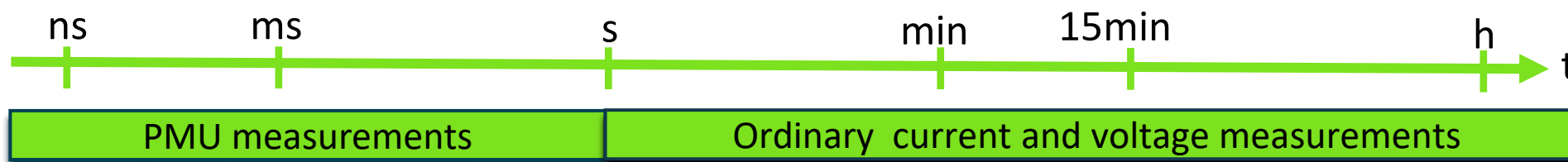
Utbygging landvind, vann- og solkraft (TWh) i Basis\*\*



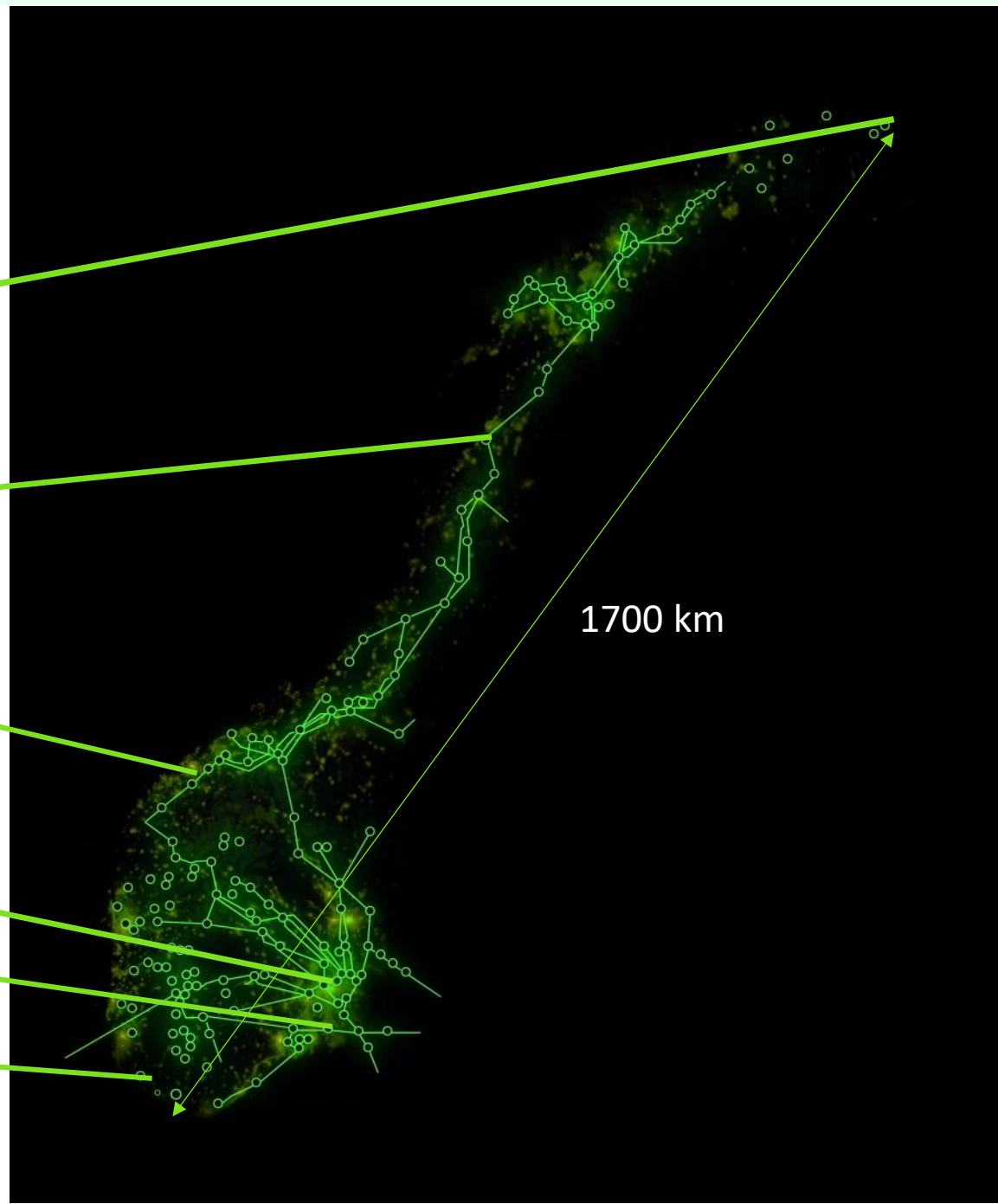
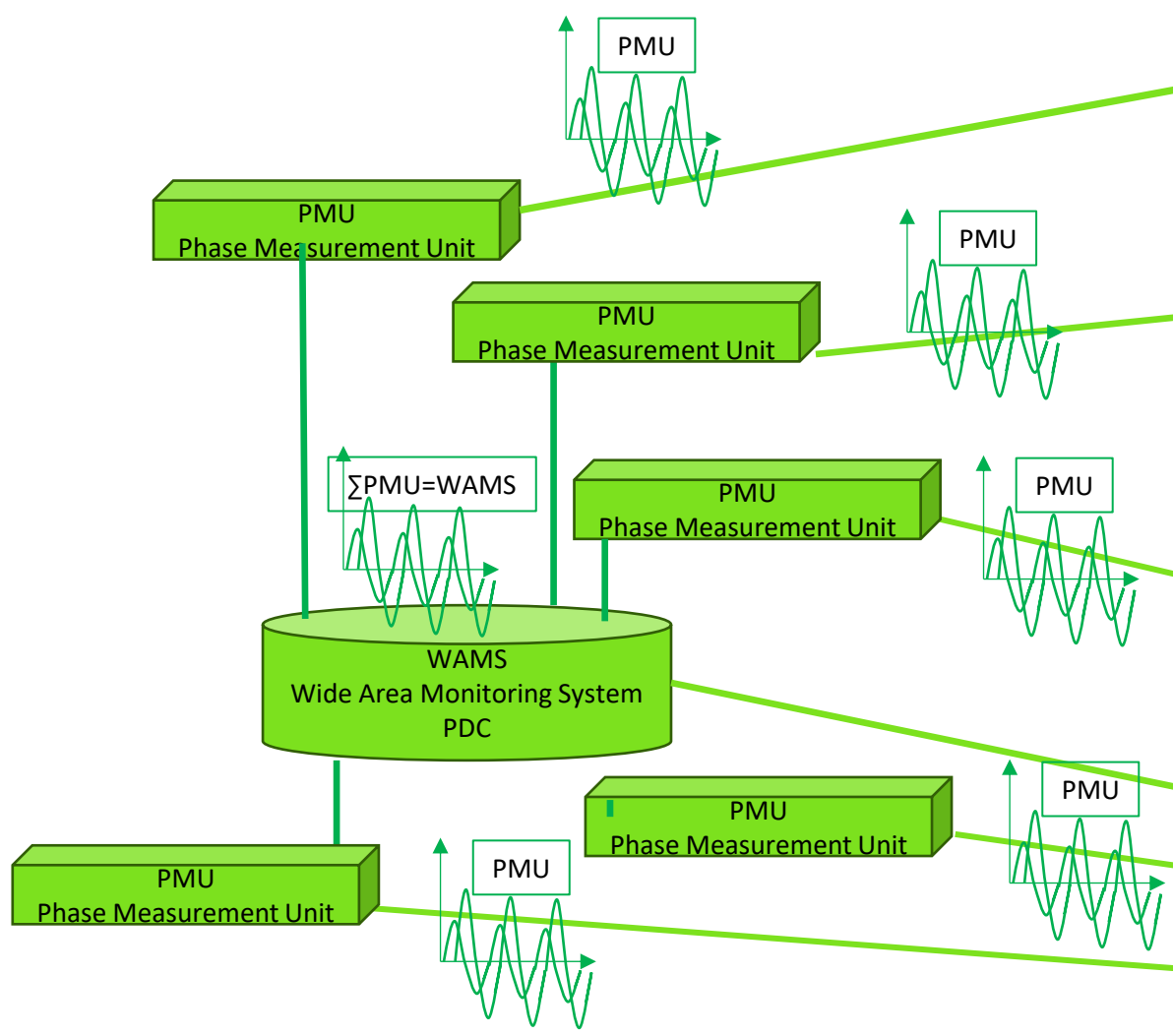
Power production change from hydro, to mix of sun and wind, connected to the grid via power electronics, gives the grid new characteristic, and needs to be monitored in a new way.



The grid needs to be monitored at millisecond level.

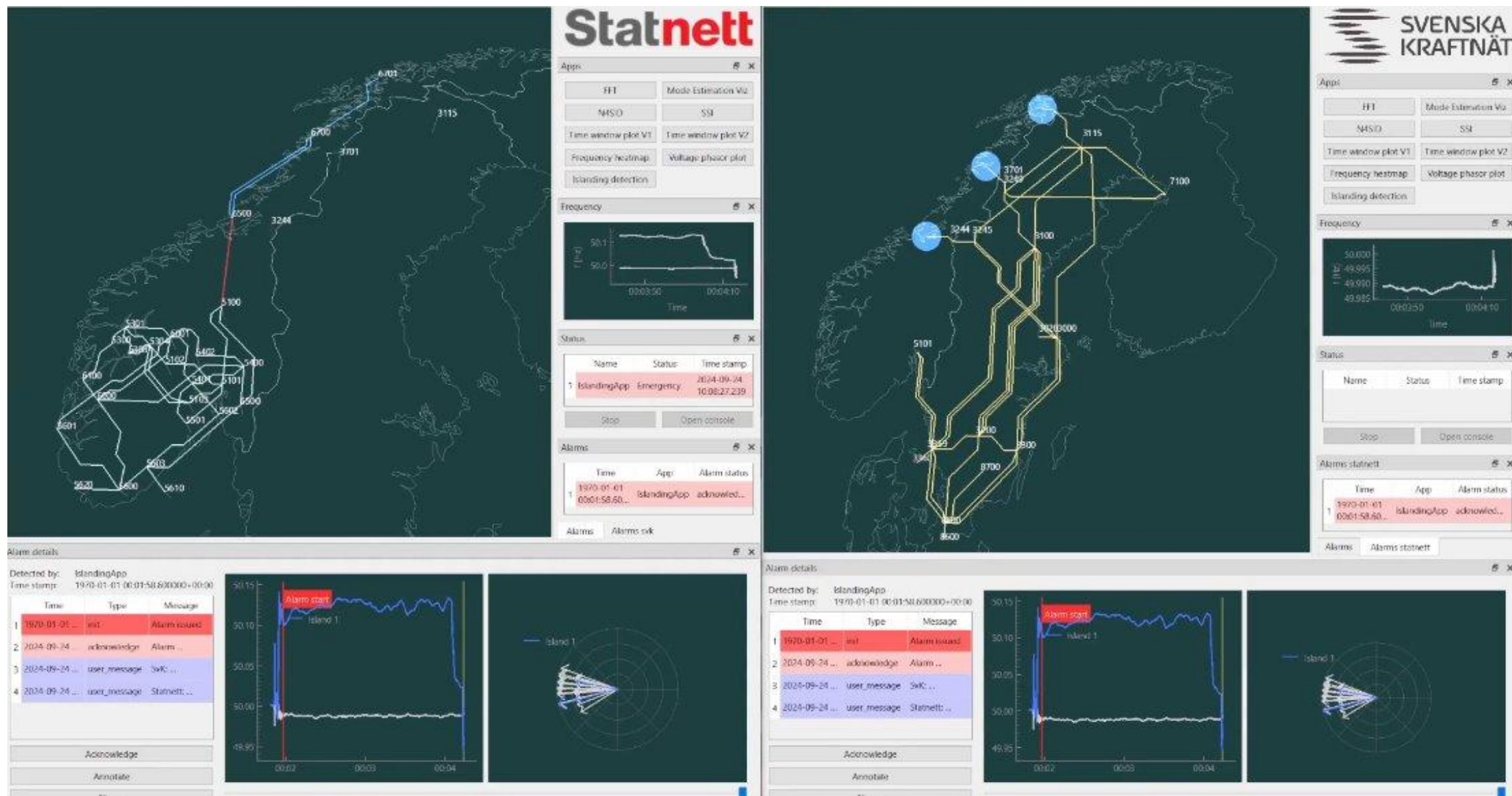


# Coordinated time- synchronization across Norway and Europe



# Alarm coordination between TSOs

## Alarm coordination between TSOs for Island detection



# All simulations based on CIM -models

The interface displays a map of Norway with a complex power grid overlaid in yellow. Numerous busbars are labeled with IDs such as 6700, 3115, 7100, 7010, 7000, 7020, 3100, 3020, 3000, 5100, 3244, 3245, 6100, 6000, 6001, 5301, 5300, 5305, 5304, 5402, 5400, 5401, 5403, 5404, 5601, 5600, 5603, 5610, 5620, 3359, 3360, 8700, 8500, 8500, 3000, and 3000. A settings window titled 'python' is open in the top-left corner, showing a 'Background color' selector and a list of layers to be displayed:

- Station names
- Buses
- Countries
- Other layers
  - Voltage phasors
  - Voltage phasors (fast)
  - Bus frequency
  - Bus voltage
  - Voltage Stability

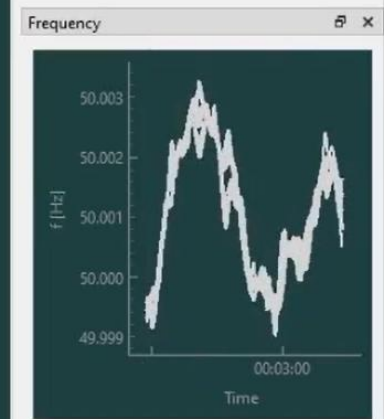
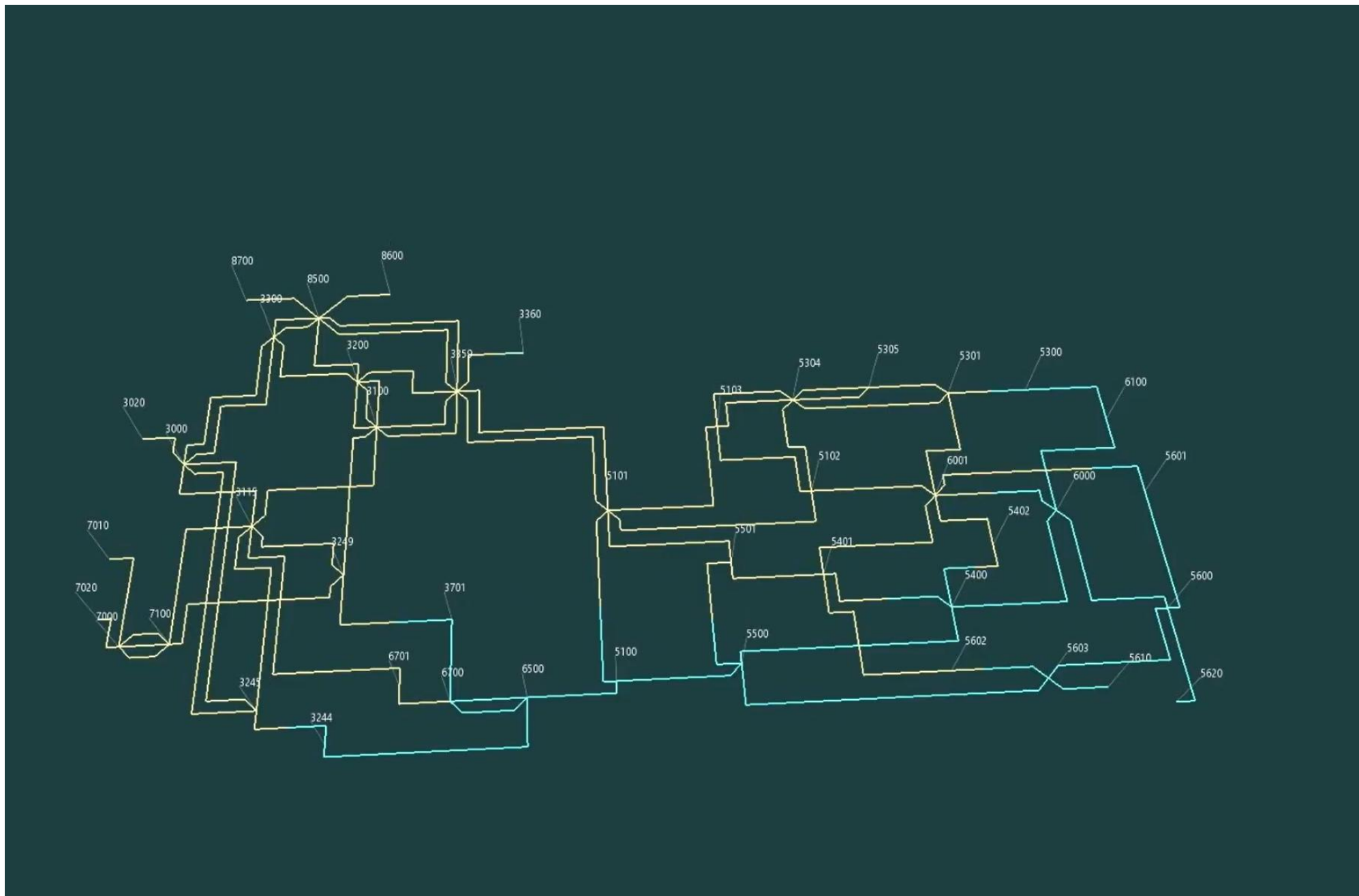
On the right side, there is a control panel with several buttons: FFT, Mode Estimation Viz, N4SID, SSI, Time window plot V1, Time window plot V2, Frequency heatmap, Voltage phasor plot, and Islanding detection. Below this panel is a 'Frequency' window showing a line graph of frequency  $f$  [Hz] over time. The y-axis ranges from 49.998 to 50.003 Hz, and the x-axis shows a time of 00:03:20. The graph shows a fluctuating frequency signal. Below the frequency plot is a 'Status' window containing a table of application status:

	Name	Status	Time stamp
1	IslandingApp	OK	2024-09-18 13:27:57.519
2	IslandingApp	OK	2024-09-18 13:29:44.651

At the bottom of the status window are 'Stop' and 'Open console' buttons. Below that is an 'Alarms' window with a table for monitoring alarm events:

Time	App	Alarm status

# All simulations based on CIM -models



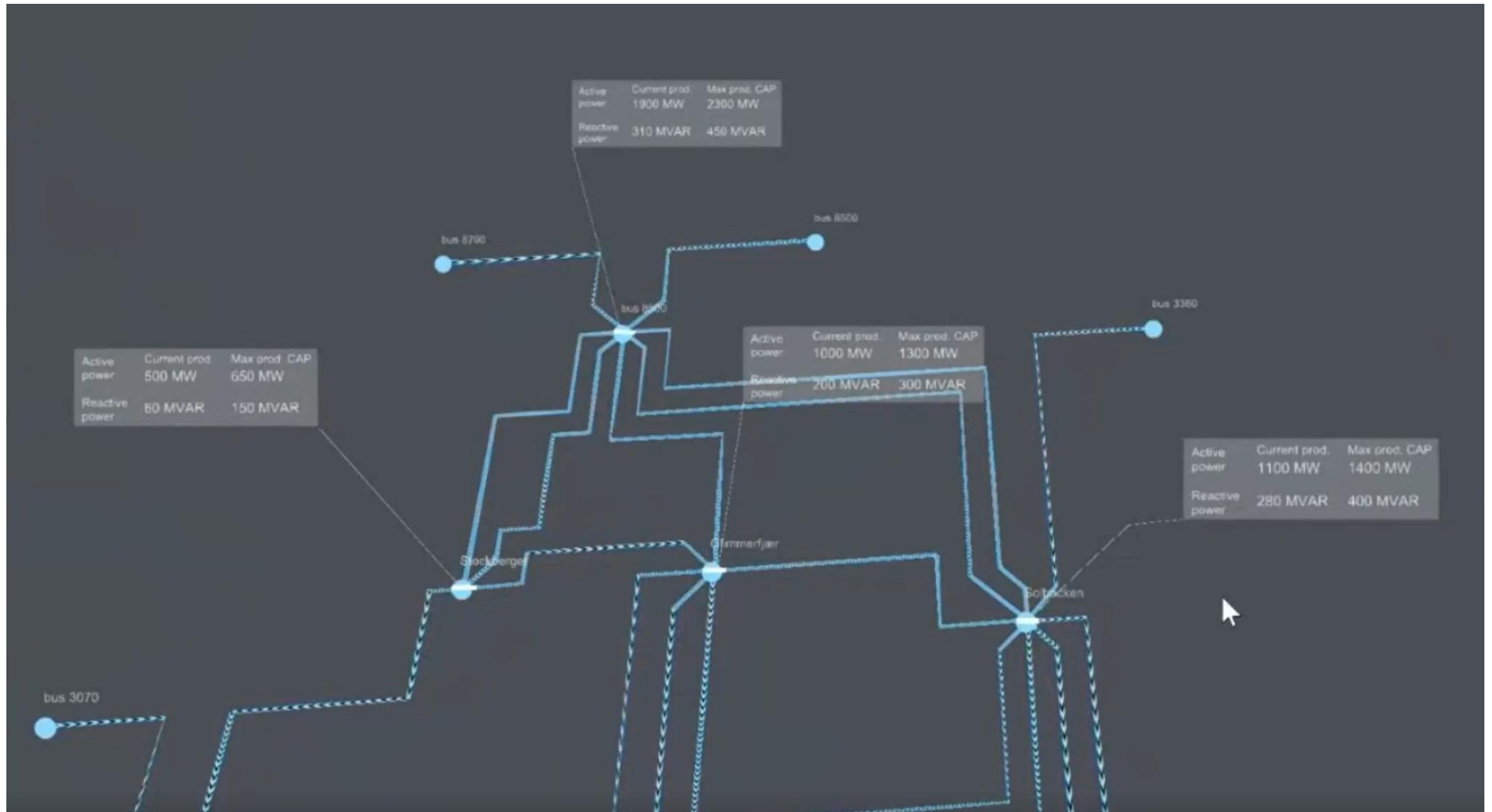
Status

Name	Status	Time stamp
1 IslandingApp	OK	2024-09-18 13:27:57.519
2 IslandingApp	OK	2024-09-18 13:29:22.650

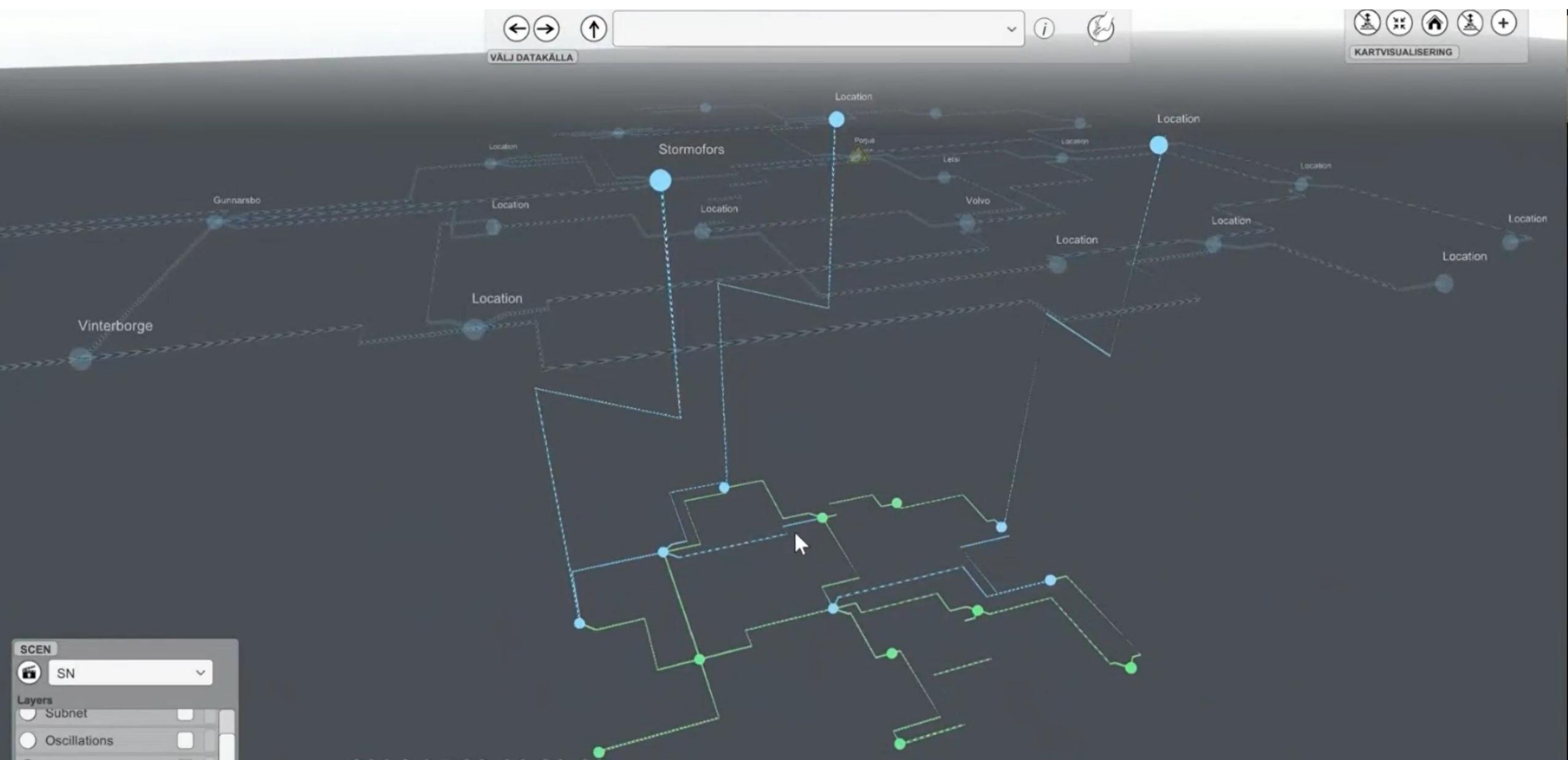
Alarms

Time	App	Alarm status

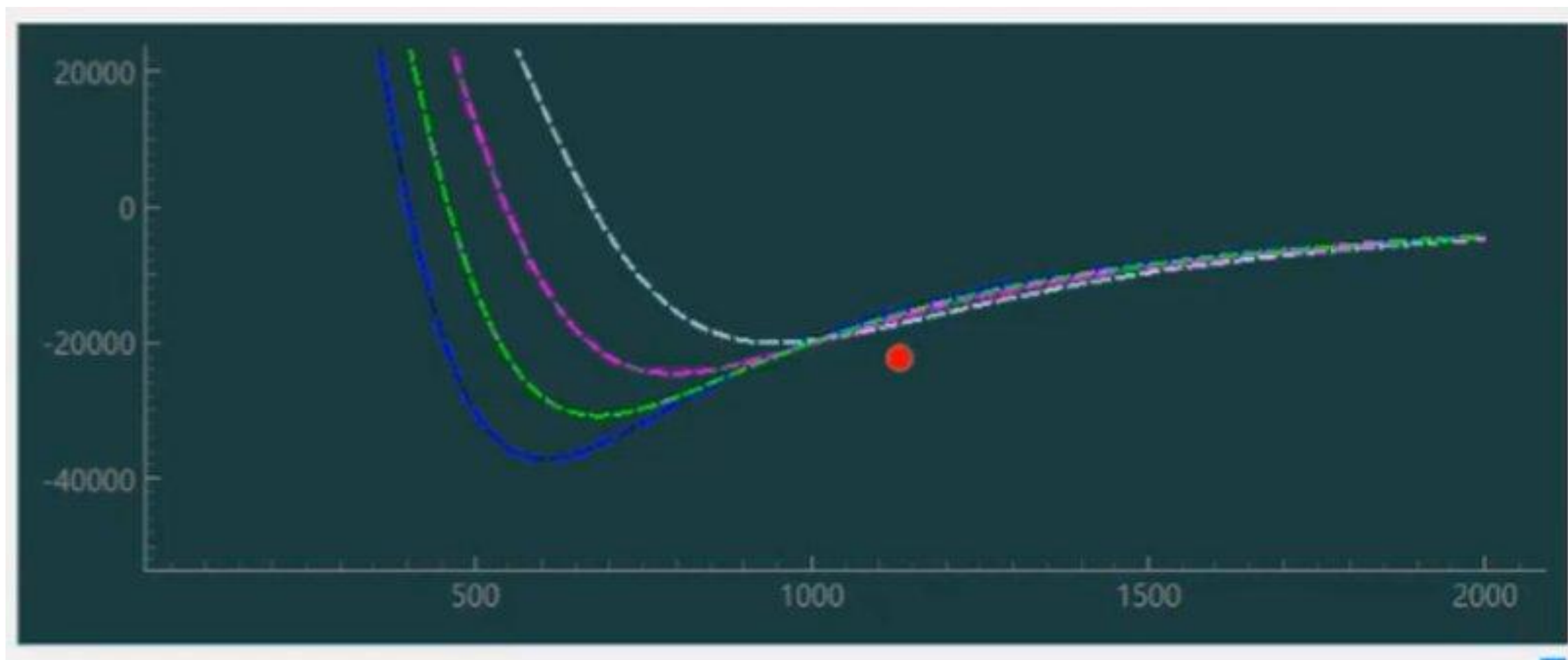
# Drill down functionality for alarm handling in sub grid by use of 3D



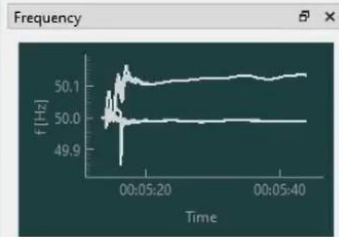
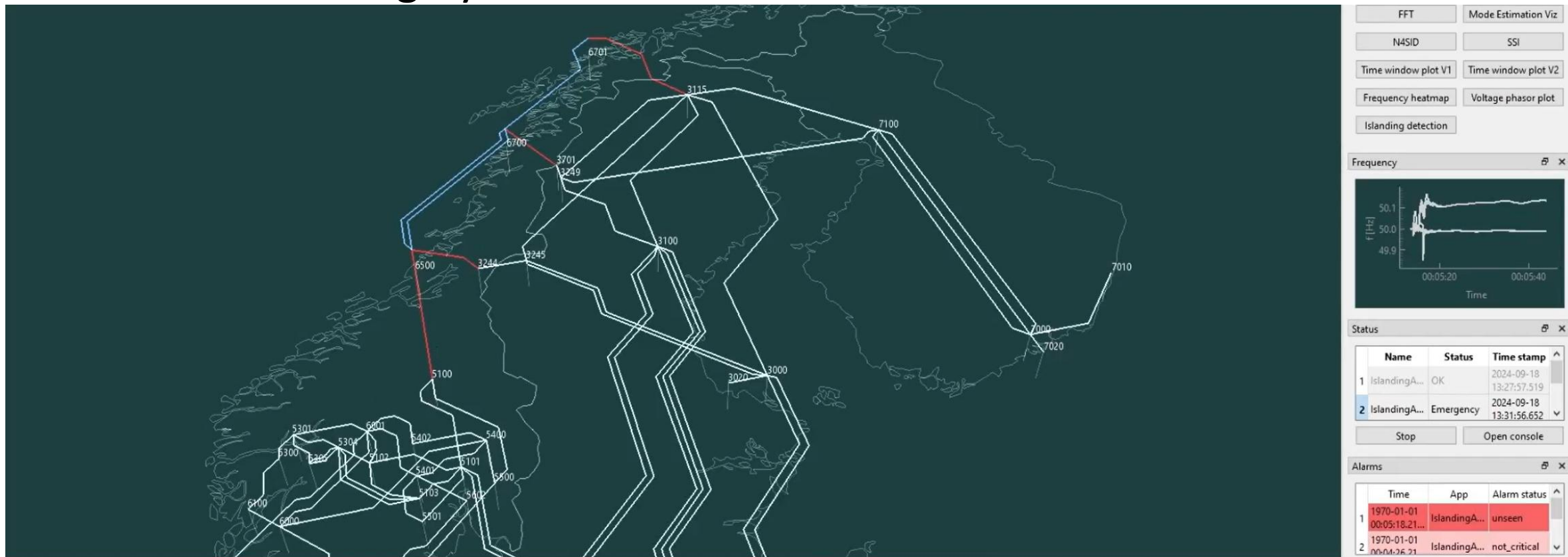
# Drill down functionality for alarm handling in sub grid by use of 3D



# Detection voltage stability



# Detection of Islanding by use of 3D



Status

Name	Status	Time stamp
1 IslandingA...	OK	2024-09-18 13:27:57.519
2 IslandingA...	Emergency	2024-09-18 13:31:56.652

Alarms

Time	App	Alarm status
1 1970-01-01 00:05:18.21...	IslandingA...	unseen
2 1970-01-01 00:04:26.21	IslandingA...	not_critical

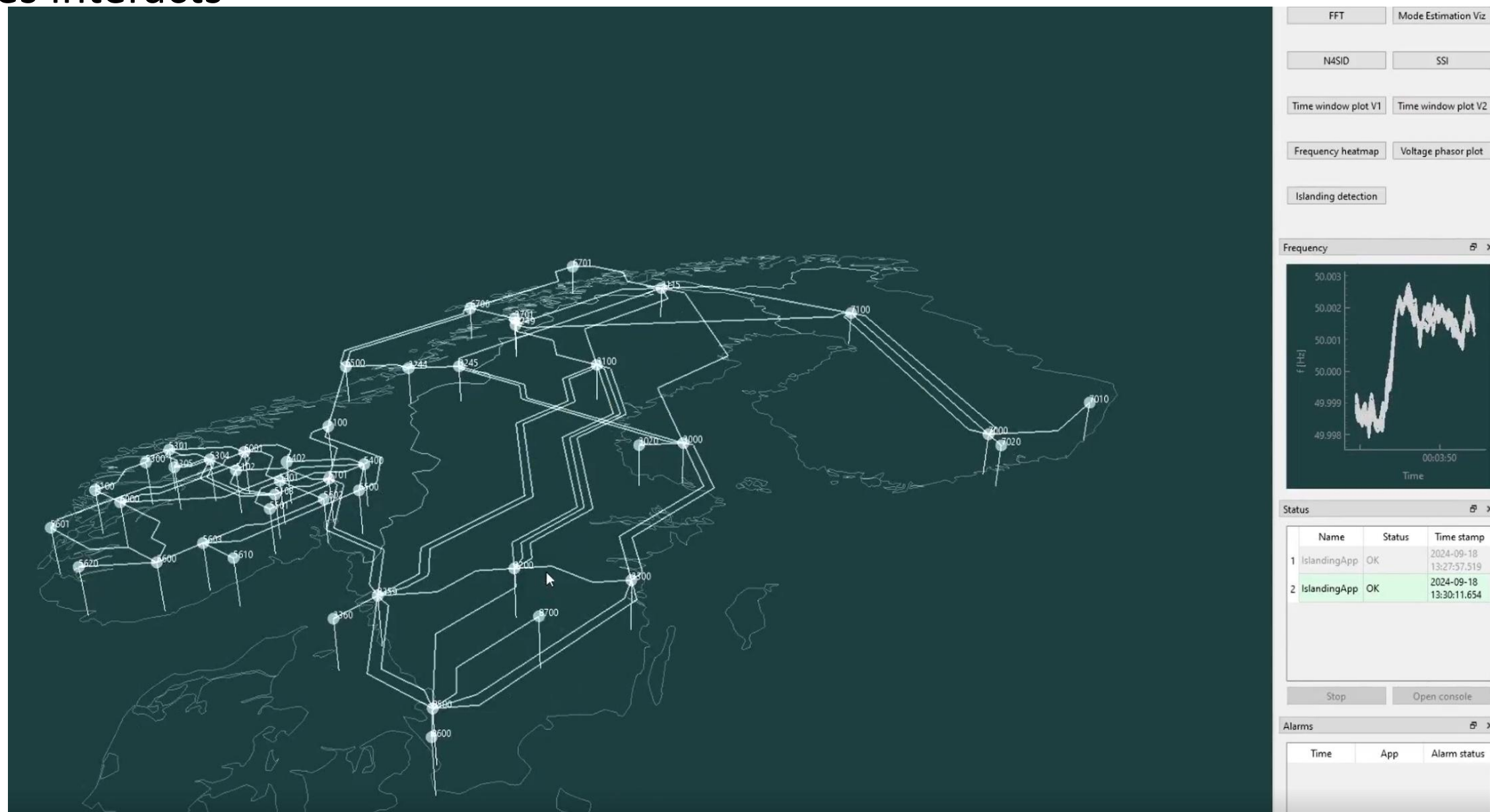
Alarm details

Detected by: IslandingApp  
 Time stamp: 1970-01-01 00:05:18.210000+00:00

Time	Type	Message
1 1970-01-01 ...	init	Alarm issued



# Oscillation detection by use of advanced UI to show how nodes interacts



# Visualization of Oscillation by use of 3D



**Statnett**

Apps

- FFT
- Mode Estimation Vt
- N4SID
- SI
- Time window plot V1
- Time window plot V2
- Frequency heatmap
- Voltage phasor plot
- Islanding detection

Frequency

Status

Name	Status	Time stamp
N4SIDApp	Emergency	2024-08-24 00:01:01+00:00

Stop    Clear console

Alarms

Time	App	Alarm status
1970-01-01 00:01:01+00:00	N4SIDApp	unset

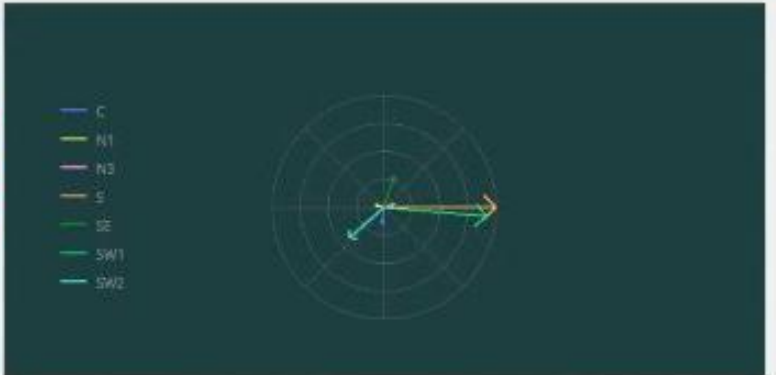
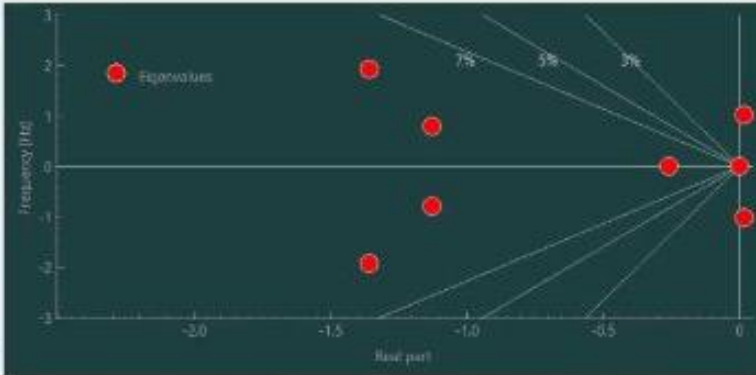
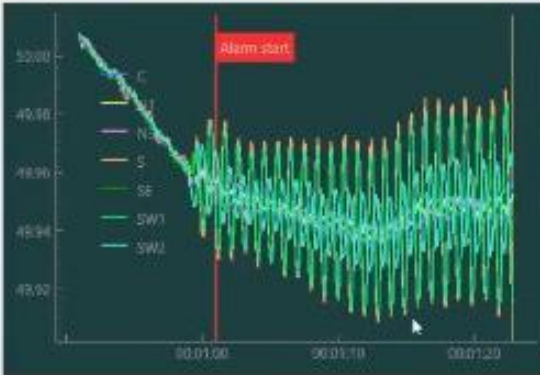
Alarm details

Detected by: N4SIDApp  
Time stamp: 1970-01-01 00:01:01+00:00

Time	Type	Message
1 1970-01-01 00:01:01+00:00	err	Alarm issued

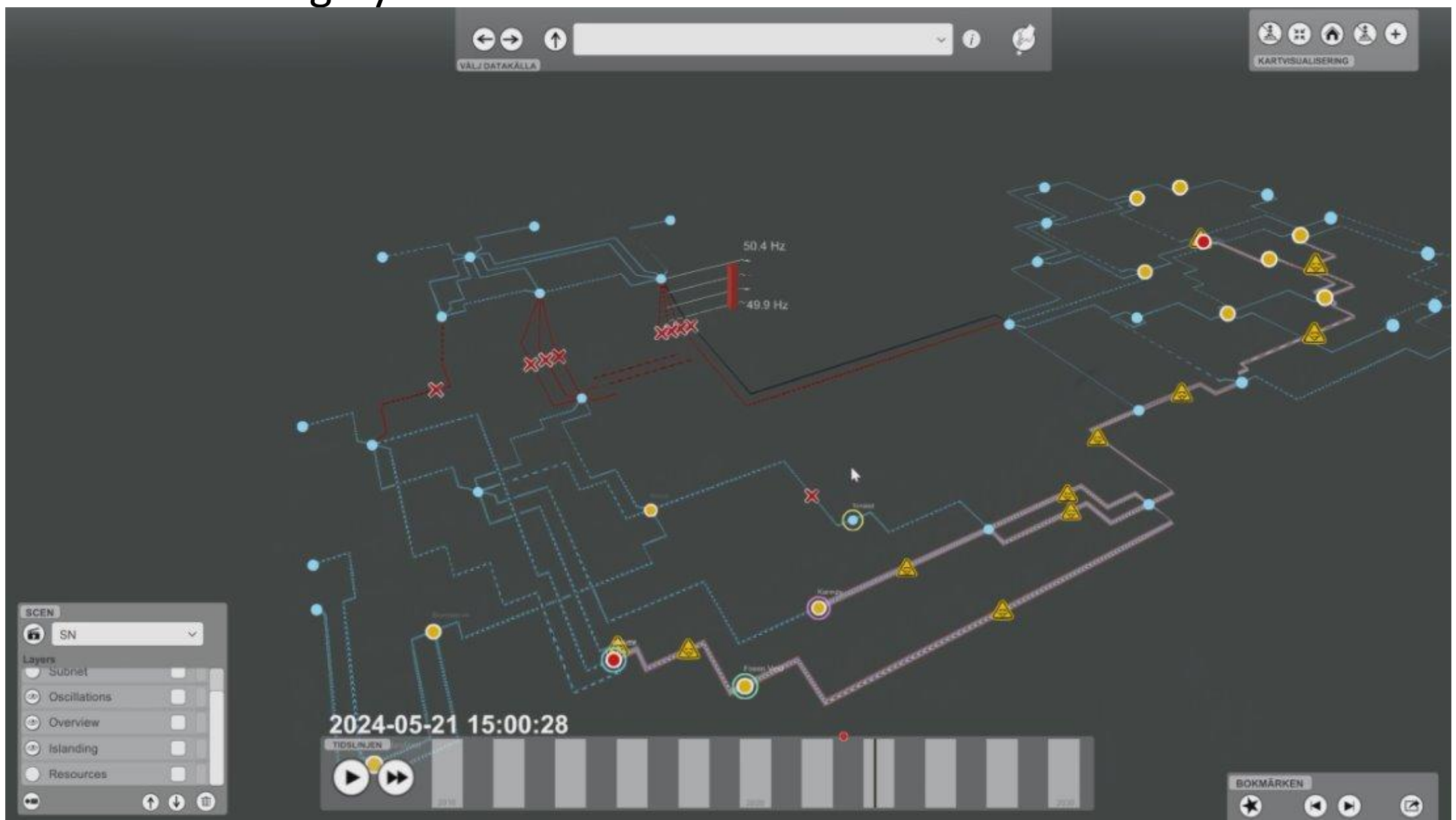
Acknowledge

Annotate



# Oscillation detection by use of advanced UI to show how nodes interacts

## Detection of Islanding by use of 3D



# Operation awareness on contingency analyze and Corrective actions

The screenshot displays the NEWEPS ASAP Panel interface, which is used for real-time monitoring and analysis of power systems. The main window shows a map of a power grid with various nodes and lines. Key data points on the map include:

- Line outage L3115-3249 (indicated by a red line)
- Line L3249-7100 Thermal overload (indicated by a red line)
- Node 7100: V=1.05
- Node 3249: AP=387.50 MW, V=1.09
- Node 3000: V=0.98
- Node 7000: 7020, AP=+369.47 MW

On the right side, there are several panels:

- Frequency:** A line graph showing frequency fluctuations over time, with a sharp spike around 00:05:20.
- Status:** A table showing the current status of contingencies.

Name	Status	Time stamp
1 Contingenc...	Undefined	2024-09-10 14:05:44.374

At the bottom, there is an **Alarm details** section with a **Contingency Analysis** list:

- C4: L3000-3245-2, line\_outage
- C5: L3000-3300-1, line\_outage
- C6: L3000-3300-2, line\_outage
- C7: L3100-3115, line\_outage
- C8: L3100-3200-1, line\_outage
- C9: L3100-3200-2, line\_outage
- C10: L3100-3200-3, line\_outage
- C11: L3100-3249, line\_outage
- C12: L3100-3359-1, line\_outage
- C13: L3100-3359-2, line\_outage
- C14: L3115-3245, line\_outage
- C15: L3115-3249, line\_outage
- C16: L3115-6701, line\_outage

Below the contingency list, there is a section for **L3249-7100: Thermal RATE1** and **3360: Voltage Stability Index**. A green dashed box highlights the **Apply corrective actions** button, which is linked to a graph showing the system's response to a contingency.

The graph at the bottom right is titled **Contingency happens (line falls out)** and shows a sharp increase in a variable (likely voltage or power) starting around 00:05:10. An arrow points from the **Apply corrective actions** button to this graph, indicating the timing of the intervention.

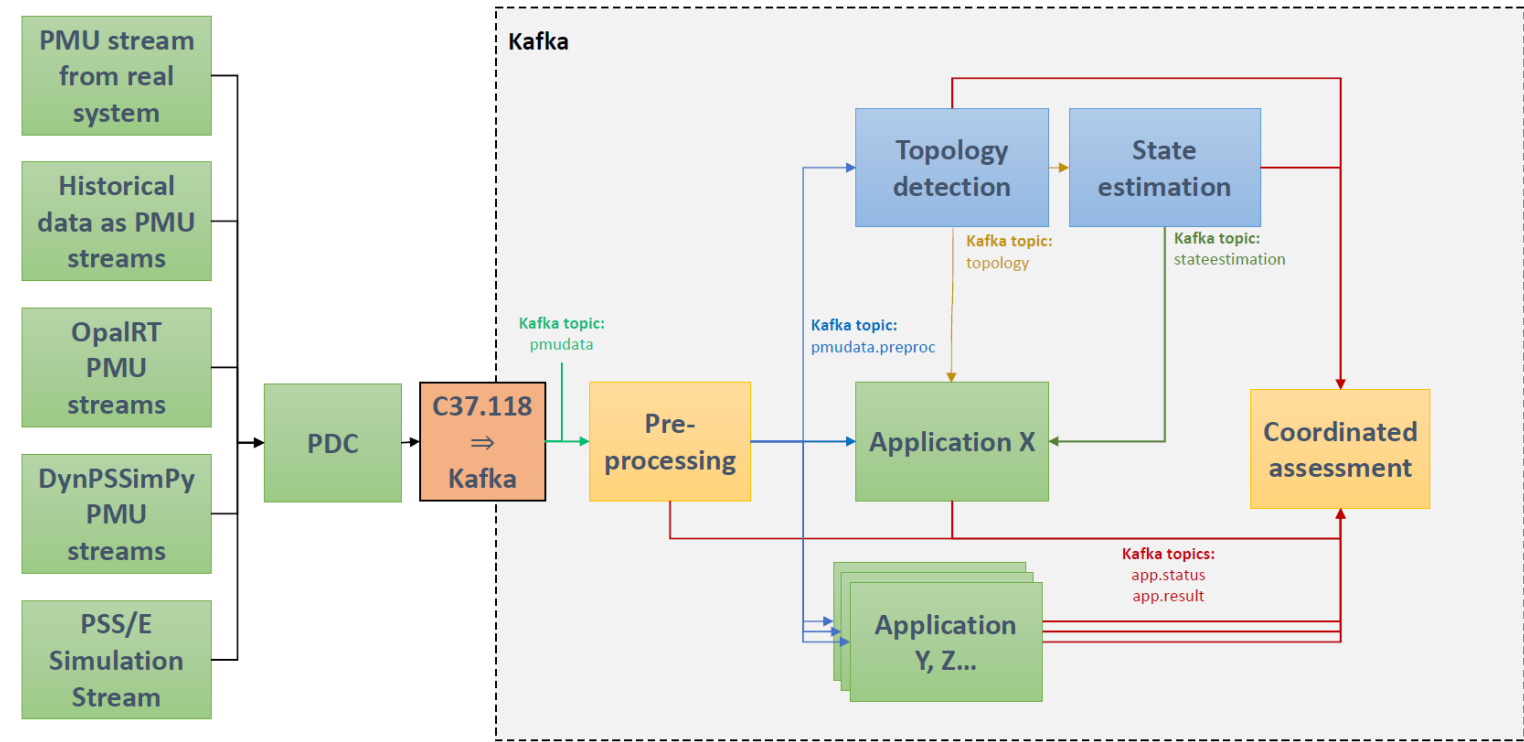
# Architecture of the implemented platform

Development of a software platform to validate the detection and visualization methods

Core programming in Python

Modular structure with several independent applications

Communication between applications with a Kafka stream



## Voltage Stability

<https://youtu.be/B2XXrjwevcs>

## Oscillations

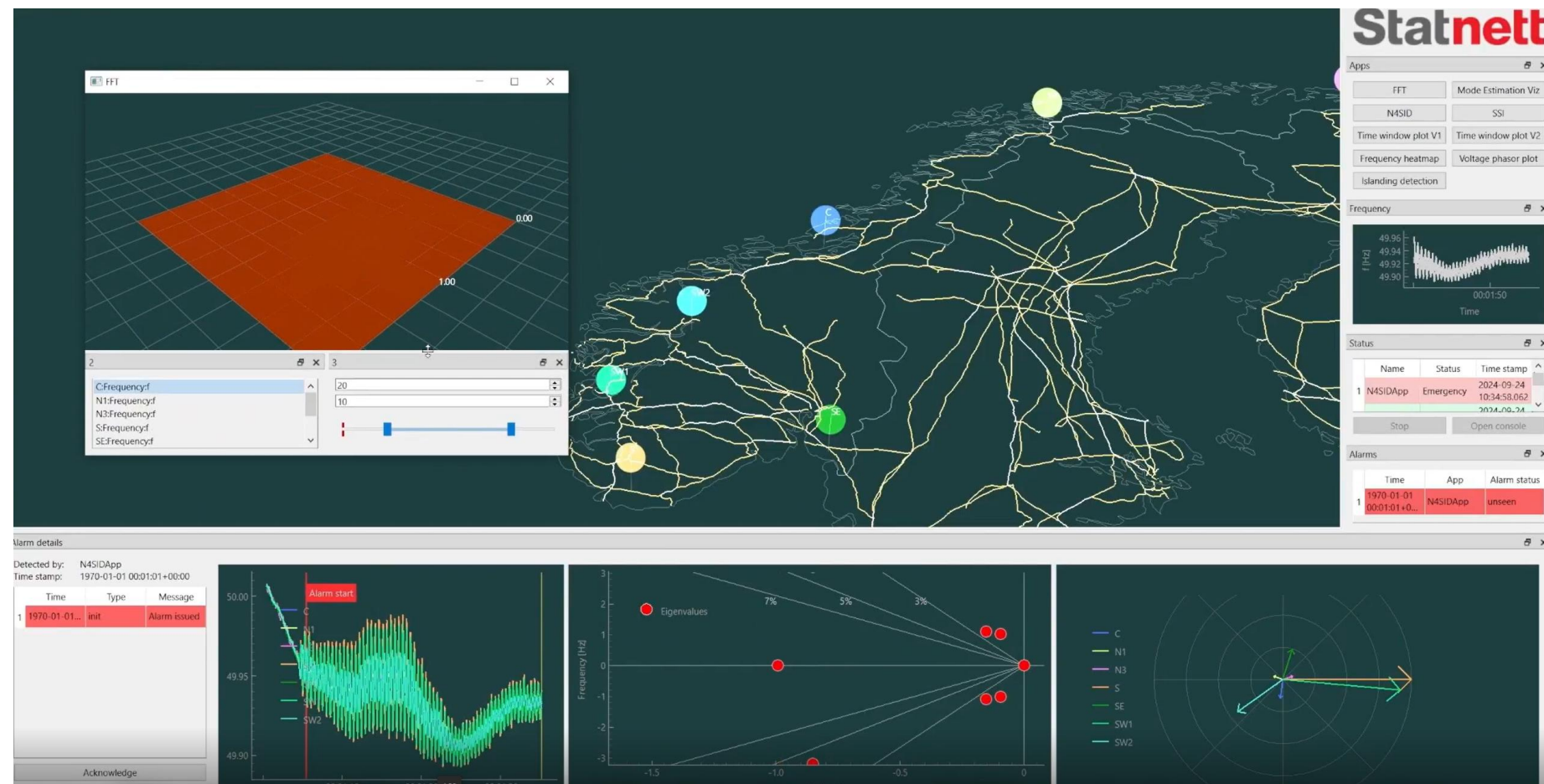
<https://youtu.be/IB7JYJ0BG9U>

## TSO Coordination

<https://youtu.be/PCm2WNXBtj0>

## SCOPF (ASAP-NEWEPS)

<https://youtu.be/wAdYy3pgG5A>



# RNDP Platform



Kubernetes hosted on Azure



Notebook interface  
(Jupyter)

Robust ecosystem for data science  
Rich visualizations  
Supports Python (mamba), R, Julia, and more



Shared POSIX filesystem (Ceph)



Kubernetes namespace  
isolation

Spark clusters for big-data workloads  
Kubernetes jobs for long-running workloads



Statnett integrated

Entra  
GitLab  
Artifactory

- **Backend**

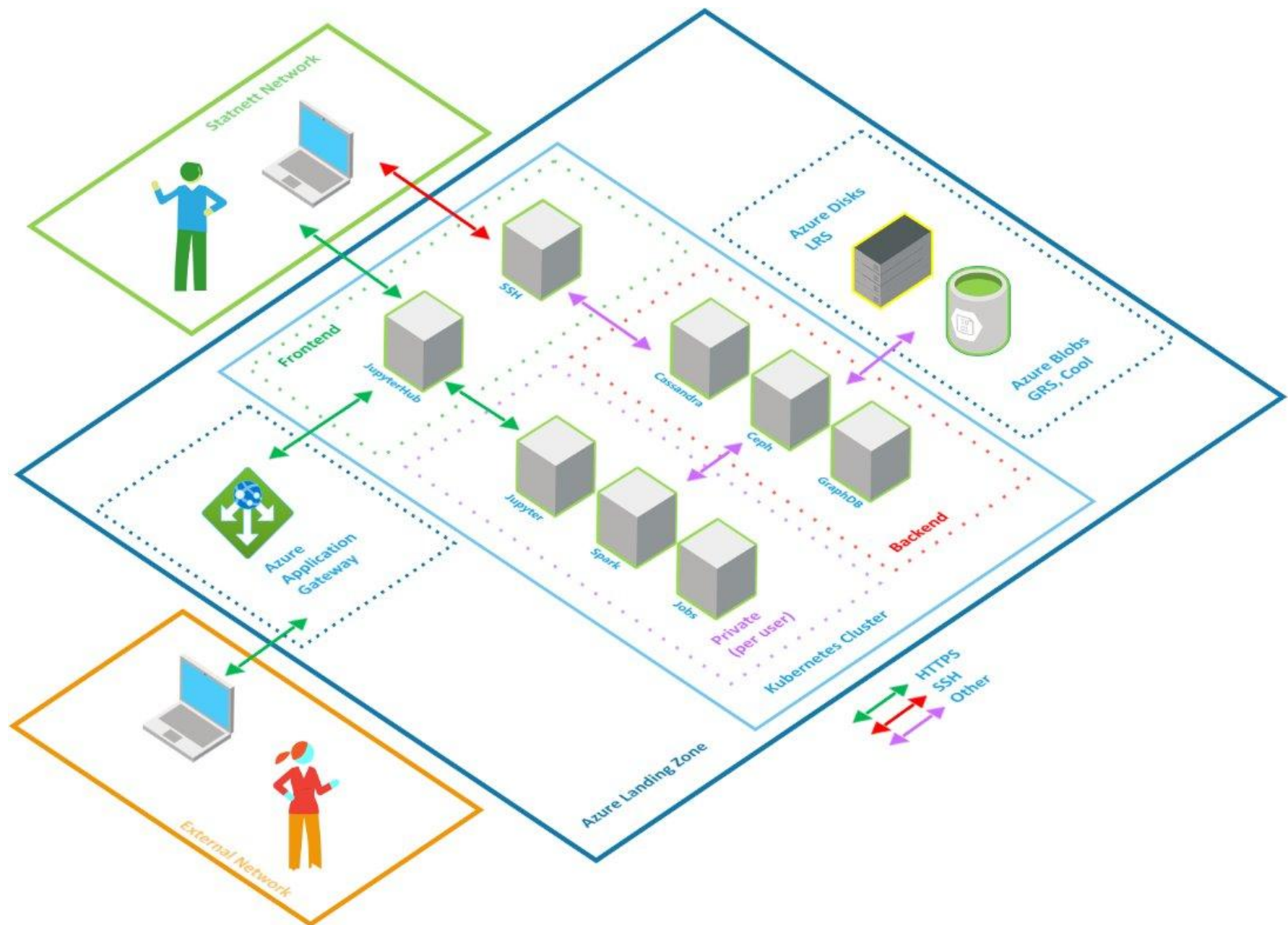
- Ceph
- Cassandra
- Hosted (GraphDB)

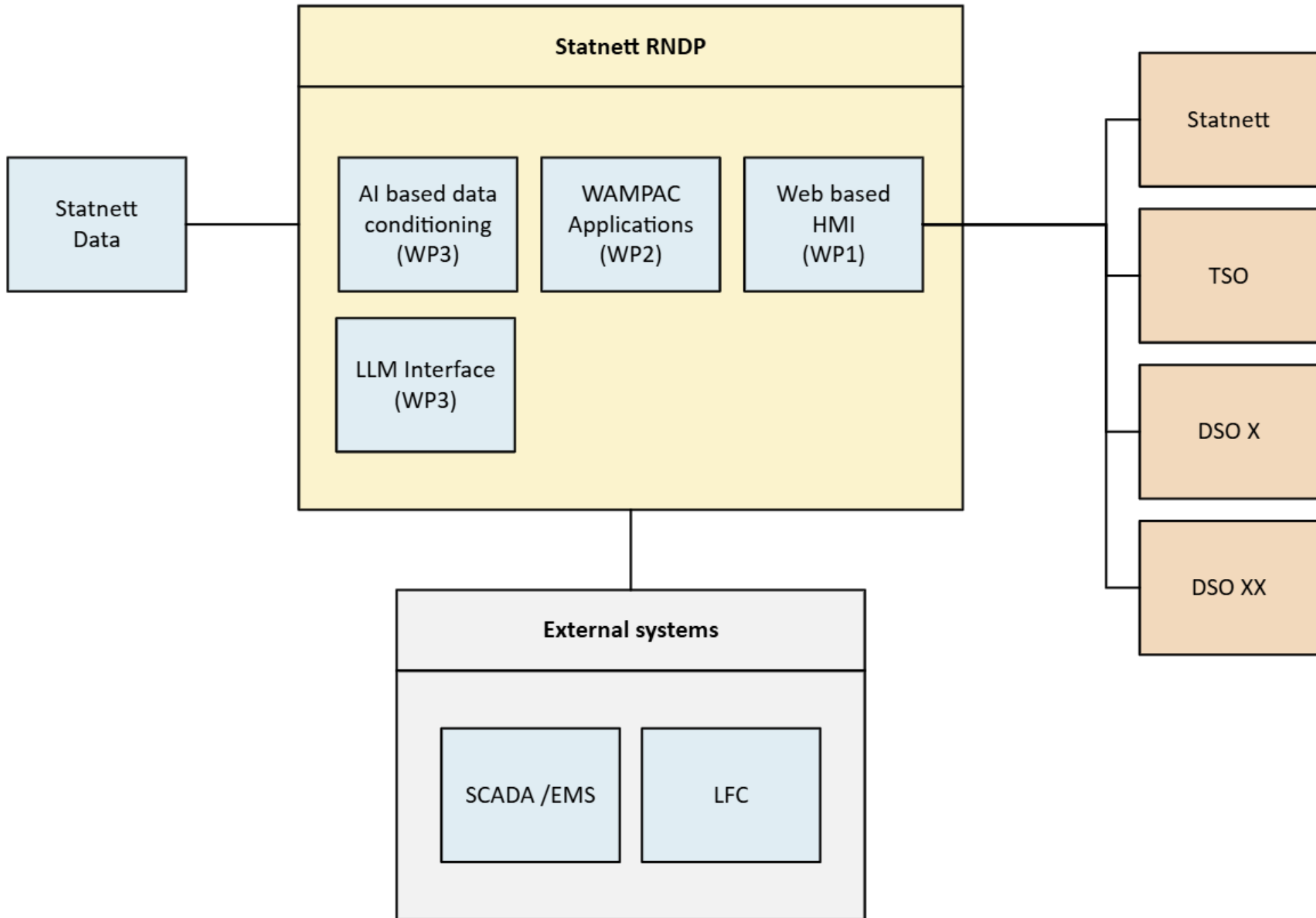
- **Frontend**

- JupyterHub
  - Services
- SSH
- Hosted

- **Private**

- Jupyter
- Spark
- Kubernetes (Jobs)





# Project p-SWAMP Tasks and work packets

- WP0 Management, communication, dissemination
- WP1 Advanced Web based HMI
- WP2 WAMPAC applications for operation support
- WP3 Data conditioning and linear state estimation
- WP4 Modules integration and deployment
- WP5 Module validations and pilot demonstration

# Project p-SWAMP timeline

Aktivitet	2026				2027				2028				2029			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
WP0 Management, communication, dissemination	■															
WP1 Advanced Web based HMI	■															
WP2 WAMPAC applications for operation support	■															
WP3 Data conditioning and linear state estimation	■															
WP4 Modules integration and deployment				■	■	■	■	■	■	■	■	■	■	■	■	■
WP5 Module validations and pilot demonstration											■	■	■	■	■	■