# NEWEPS

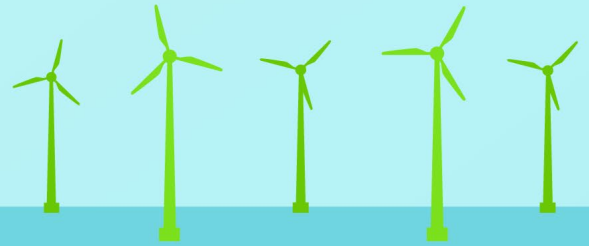
## Nordic Early Warning Early Prevention System

Kjetil Obstfelder Uhlen

Statnett

# Outline

- Introduction - What is NEWEPS about?
- Phasors and Phasor Measurements
- NEWEPS project - plans and ambitions
  - N – Nordic
  - EW – Early Warning
  - EP – Early Prevention
  - S - System
- Expected results and way forward



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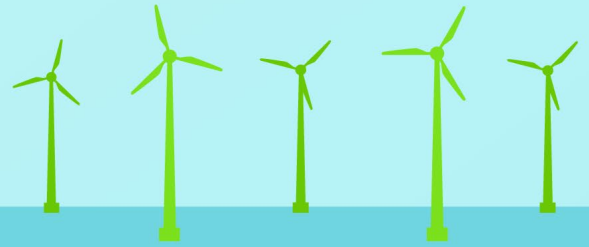
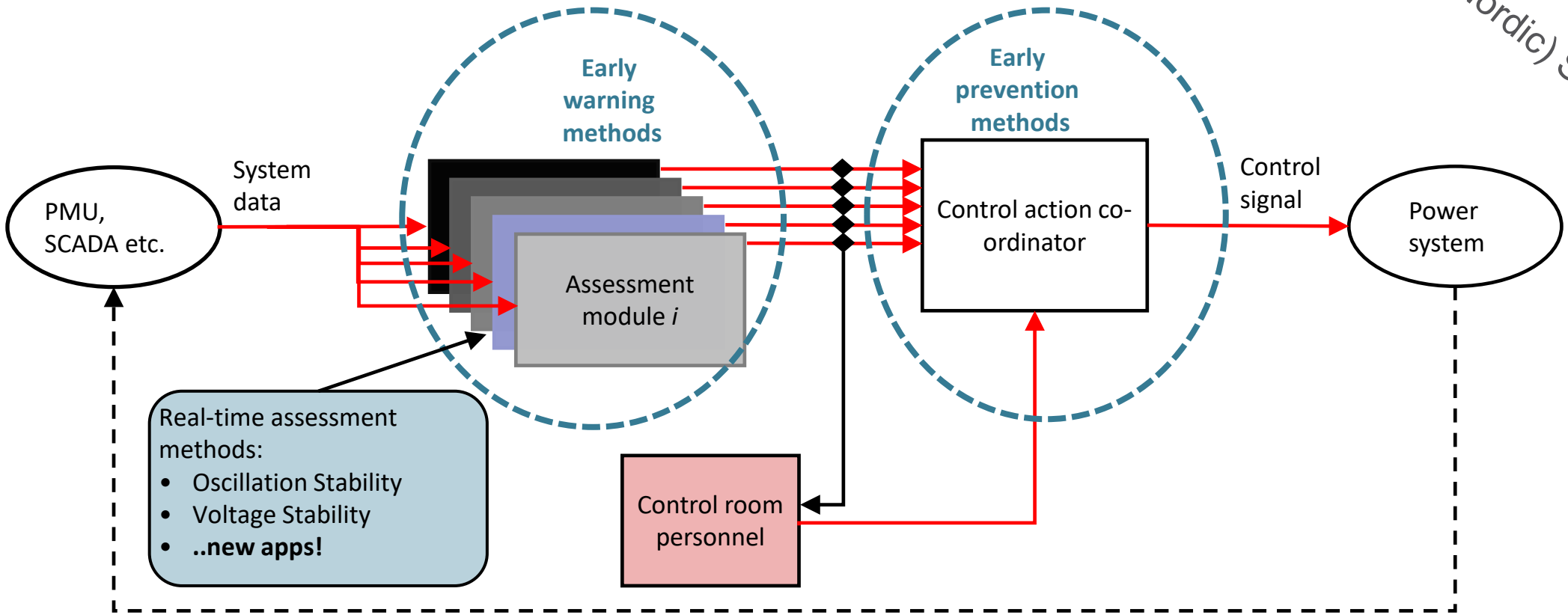


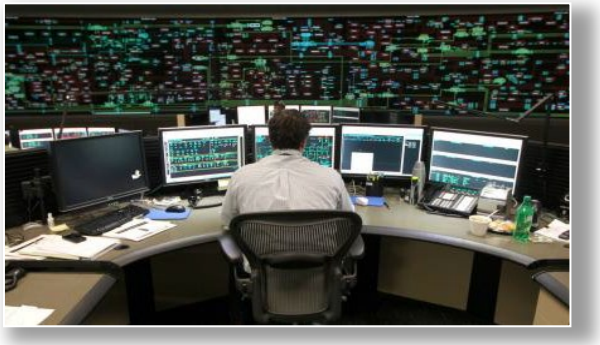
# NEWEPS is a research and innovation project

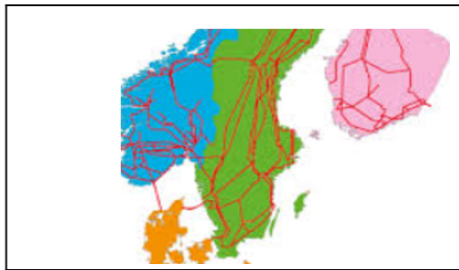
- Develop methods and algorithms for early detection of critical operating situations
- Demonstrate models and applications for improved and coordinated decision support
- .. into a prototype IT-platform (getting closer to the operational environment)

Early Warning
Early Prevention
(Nordic) System



# NEWEPS builds on the use of PMU-data in operation






**1 vs. 500**
*(observations per 10 sec)*

- SCADA/EMS today: *Mostly static information – not synchronised*
- *Power system dynamics becoming faster and more complex*
  - ➢ *Increasingly critical to monitor stability properties to improve control*

PMU

- ***Synchronized measurements of Voltages, Currents and Frequency every 20 ms.***
  - ➢ ***Create possibilities to improve decision support and automatic control***

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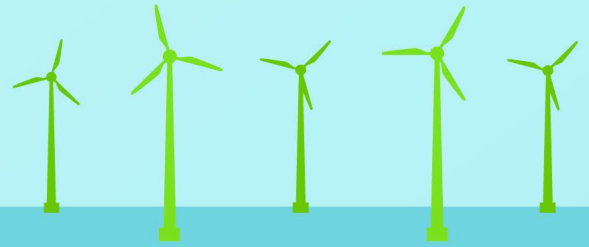
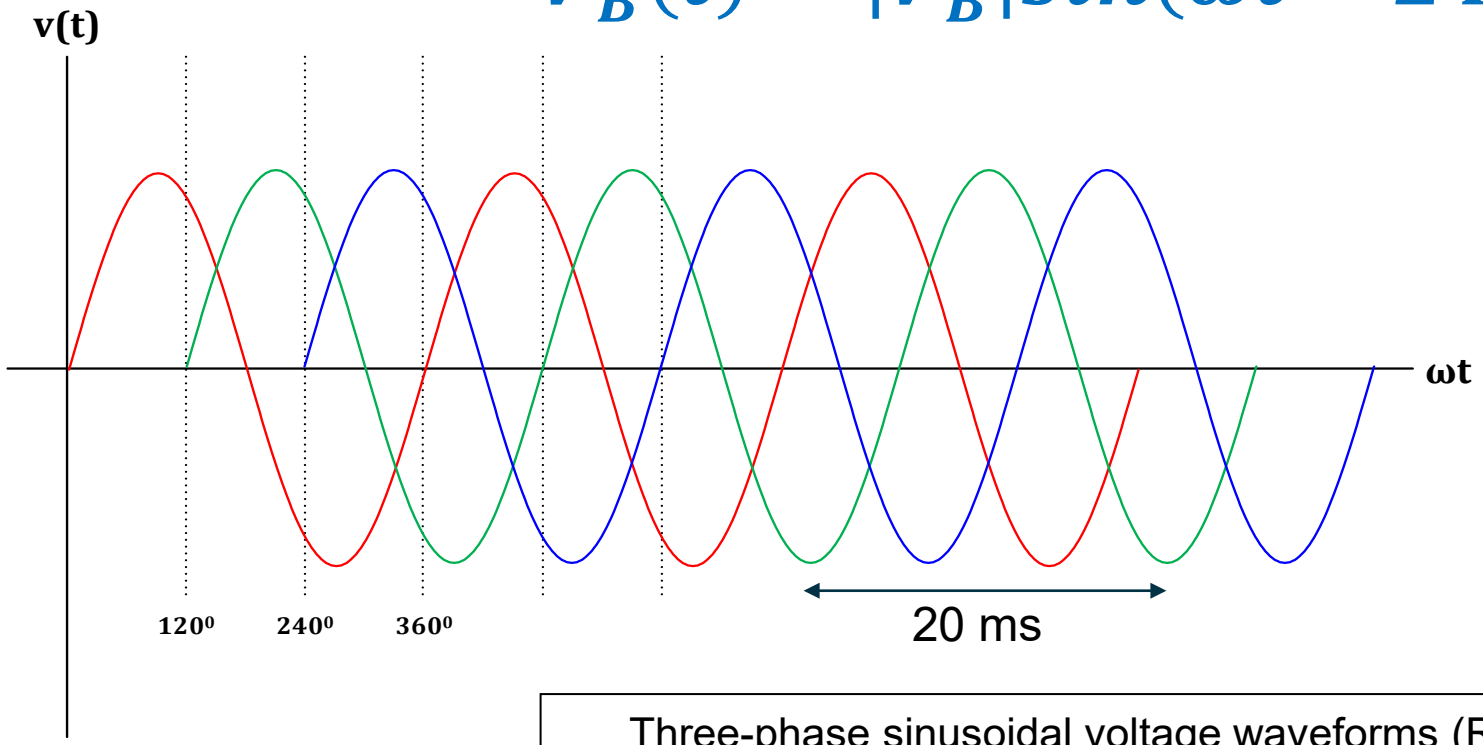


# Voltage and current waveforms

$$V_R(t) = |V_R|sin(\omega t)$$
$$V_Y(t) = |V_Y|sin(\omega t - 120°)$$
$$V_B(t) = |V_B|sin(\omega t - 240°)$$

Same peak values, if symmetric system

$|V_R| = |V_Y| = |V_B|$

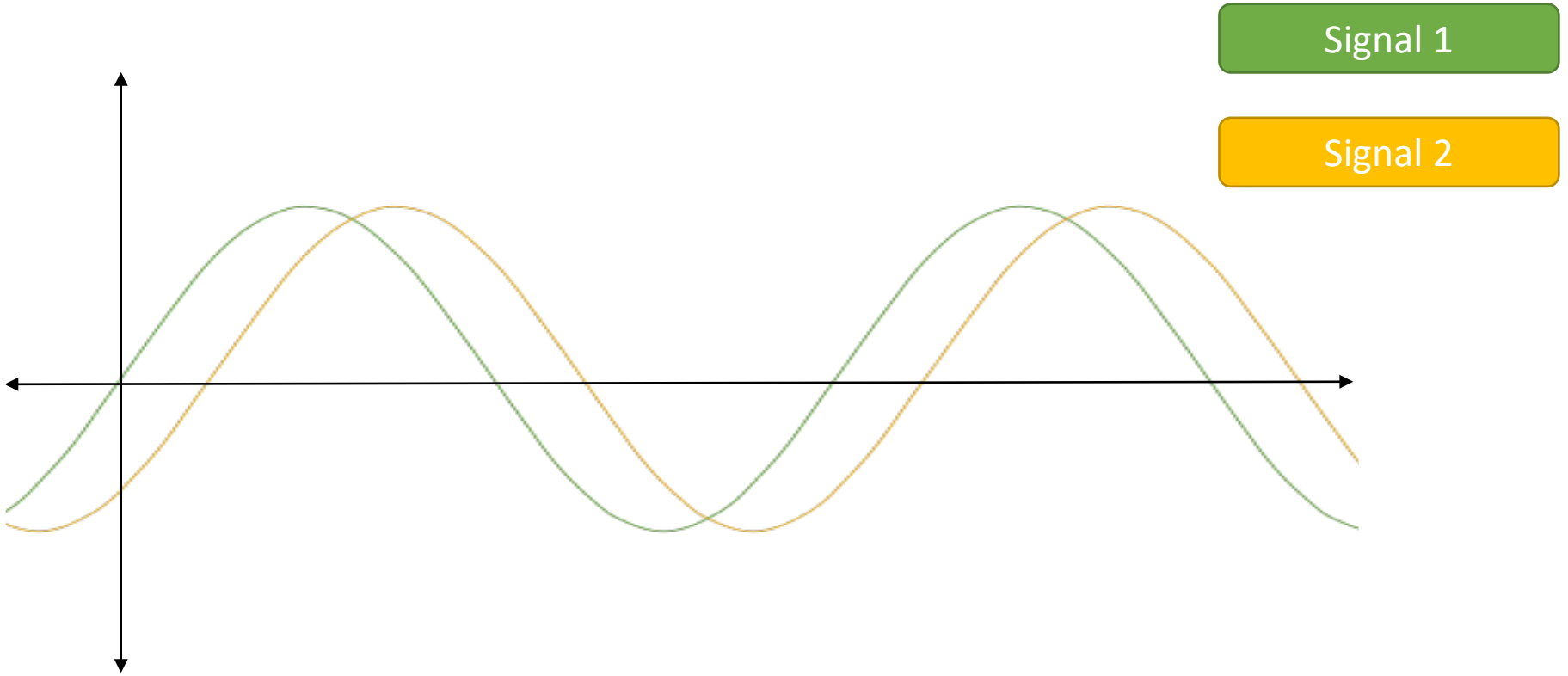



Three-phase sinusoidal voltage waveforms (R-Y-B sequence)

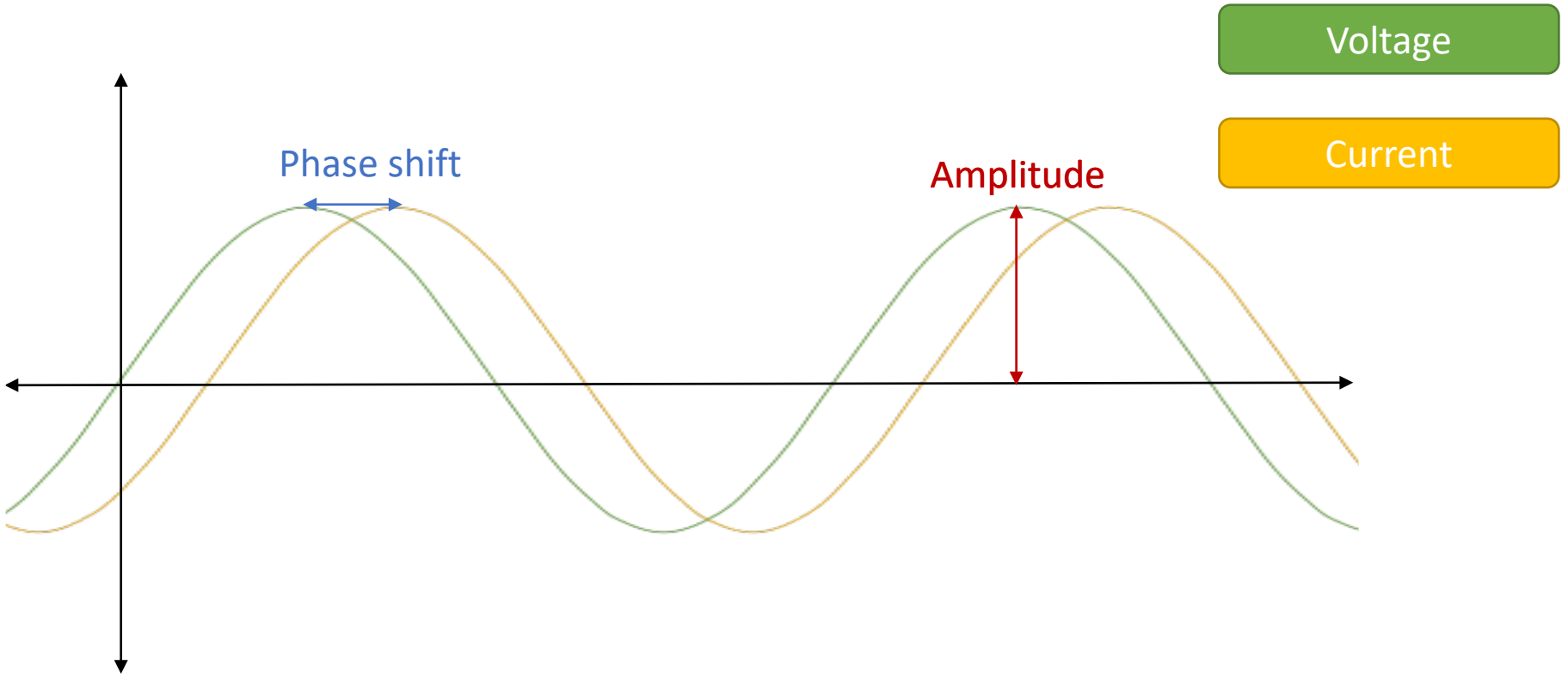
**PMU ?**

**What are *Phasors*?**
**Why synchronised measurements?**

# Time Synchronized signals



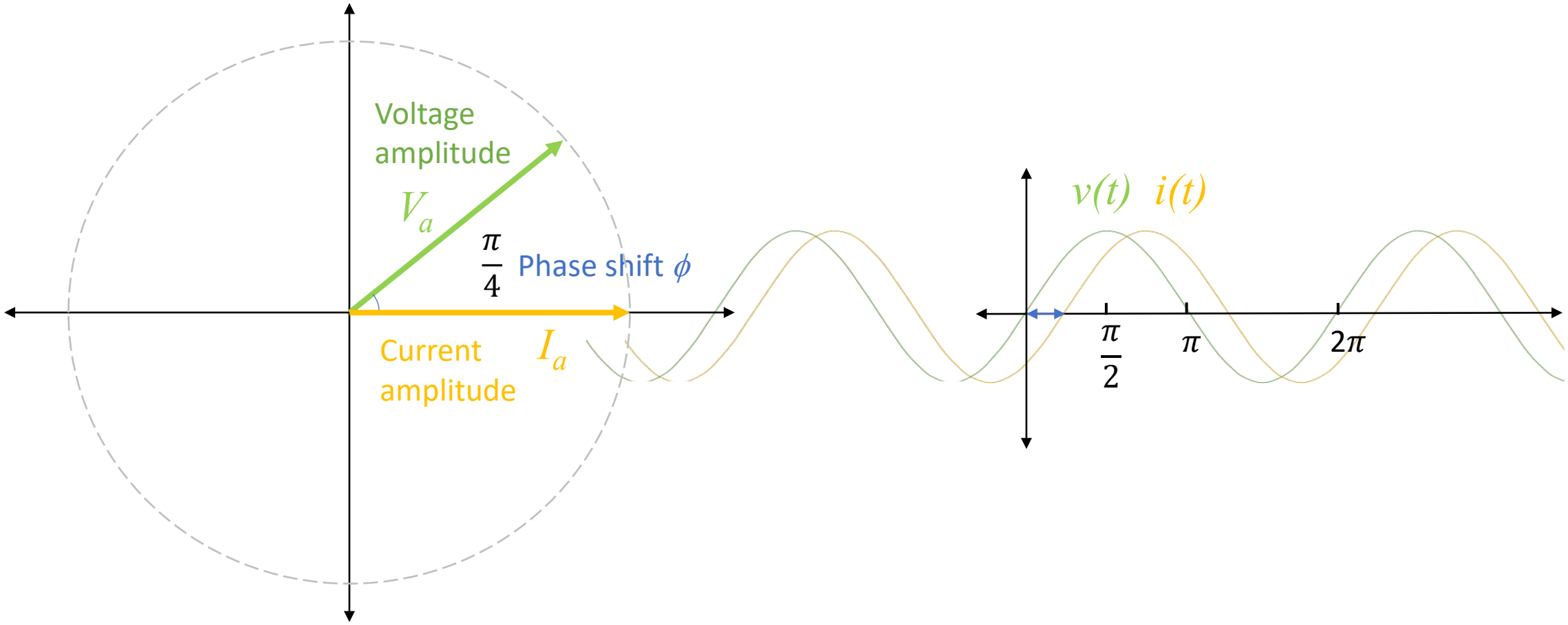
# Voltage and currents in time



# Phasor representation

Voltage

Current



# Phasor representation

Voltage

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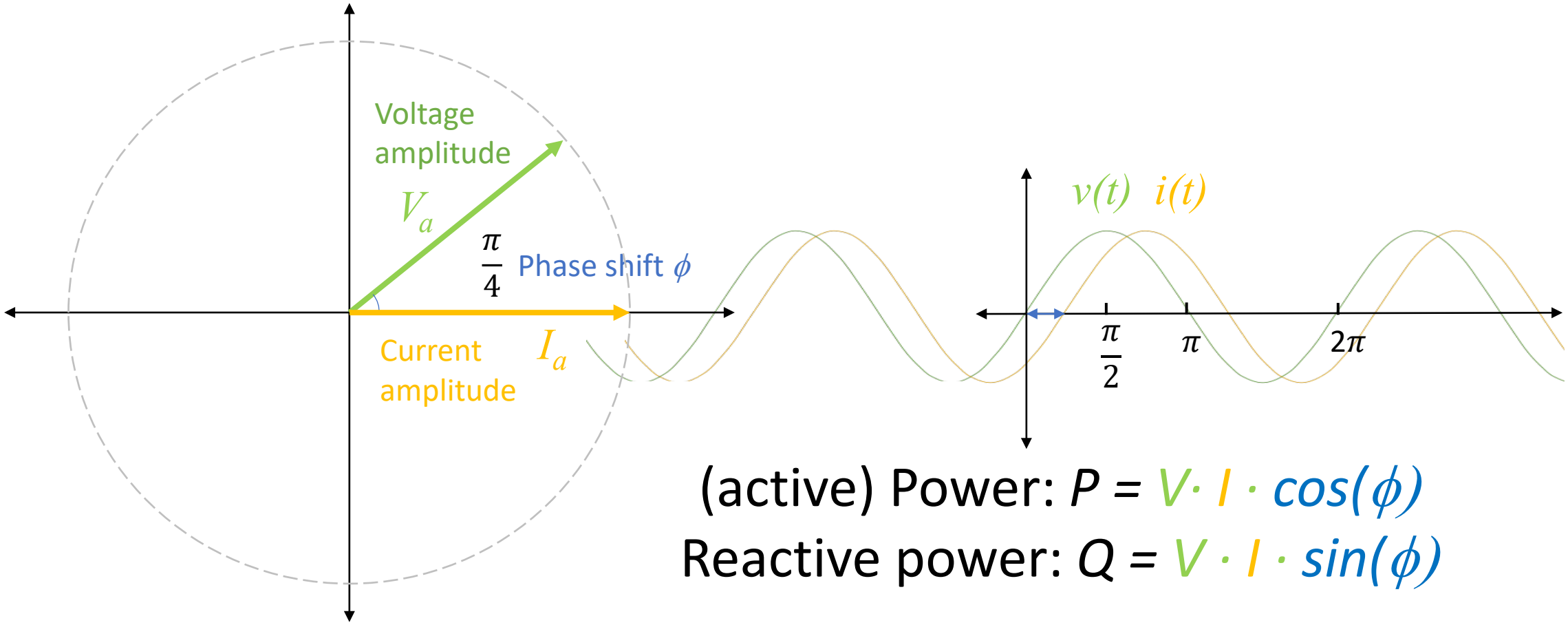
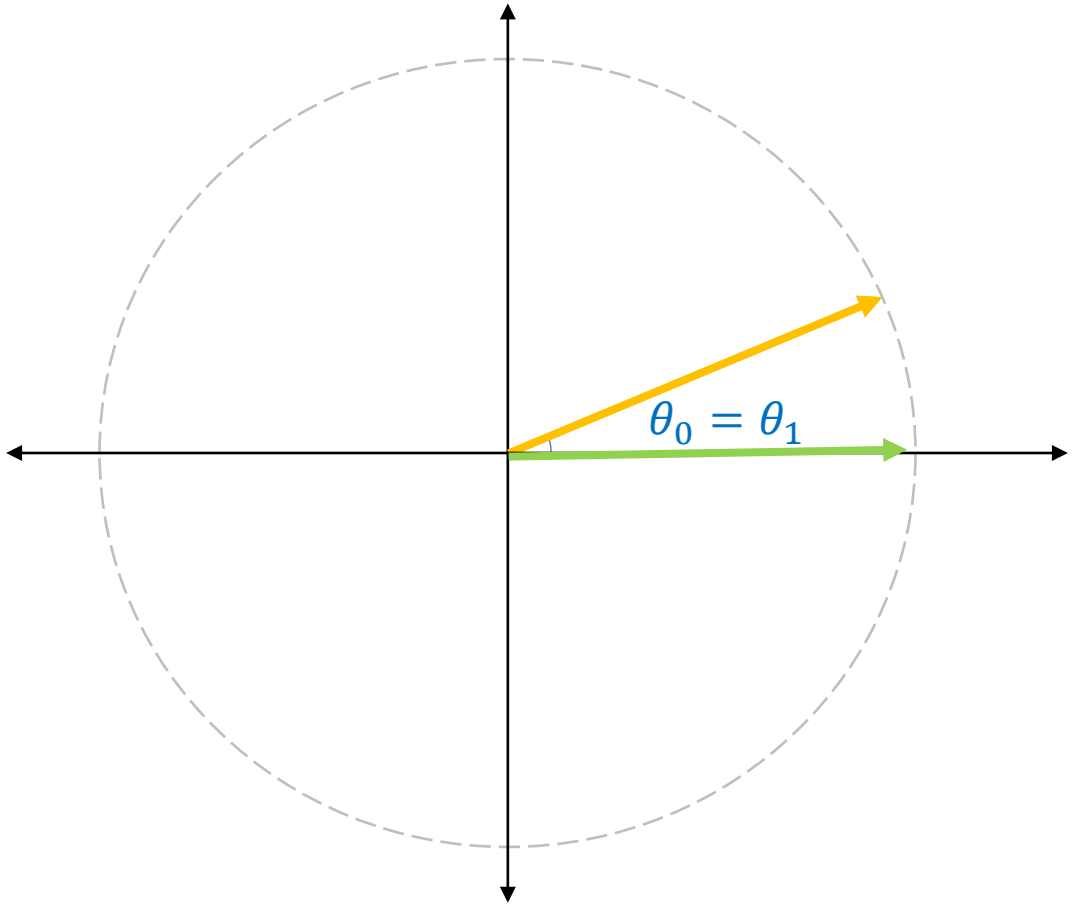


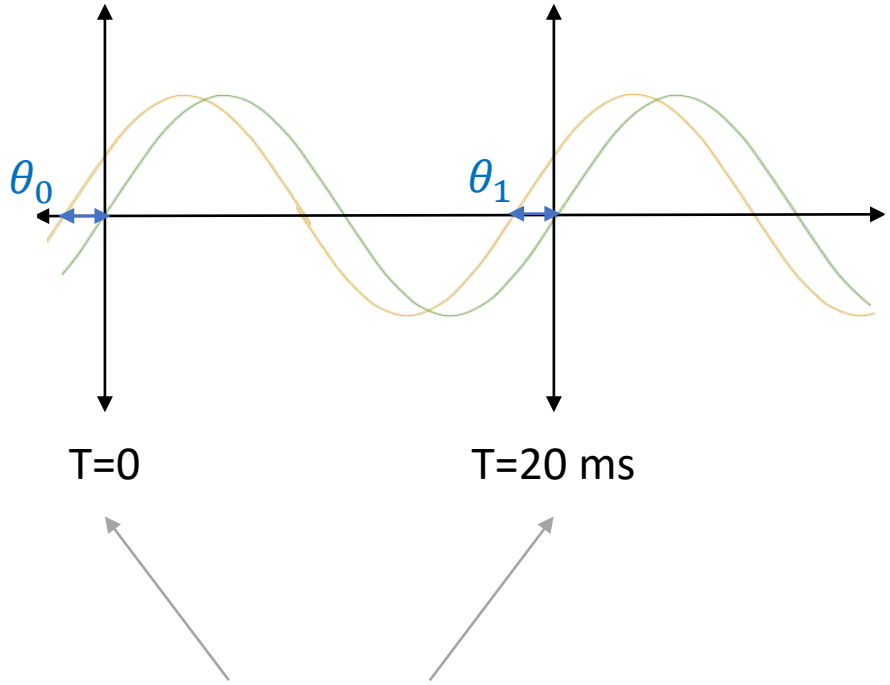

(active) Power: $P = V \cdot I \cdot \cos(\phi)$

Reactive power: $Q = V \cdot I \cdot \sin(\phi)$

*RMS (Root-mean-square ):* $V = V_{RMS} = V_a / \sqrt{2}$

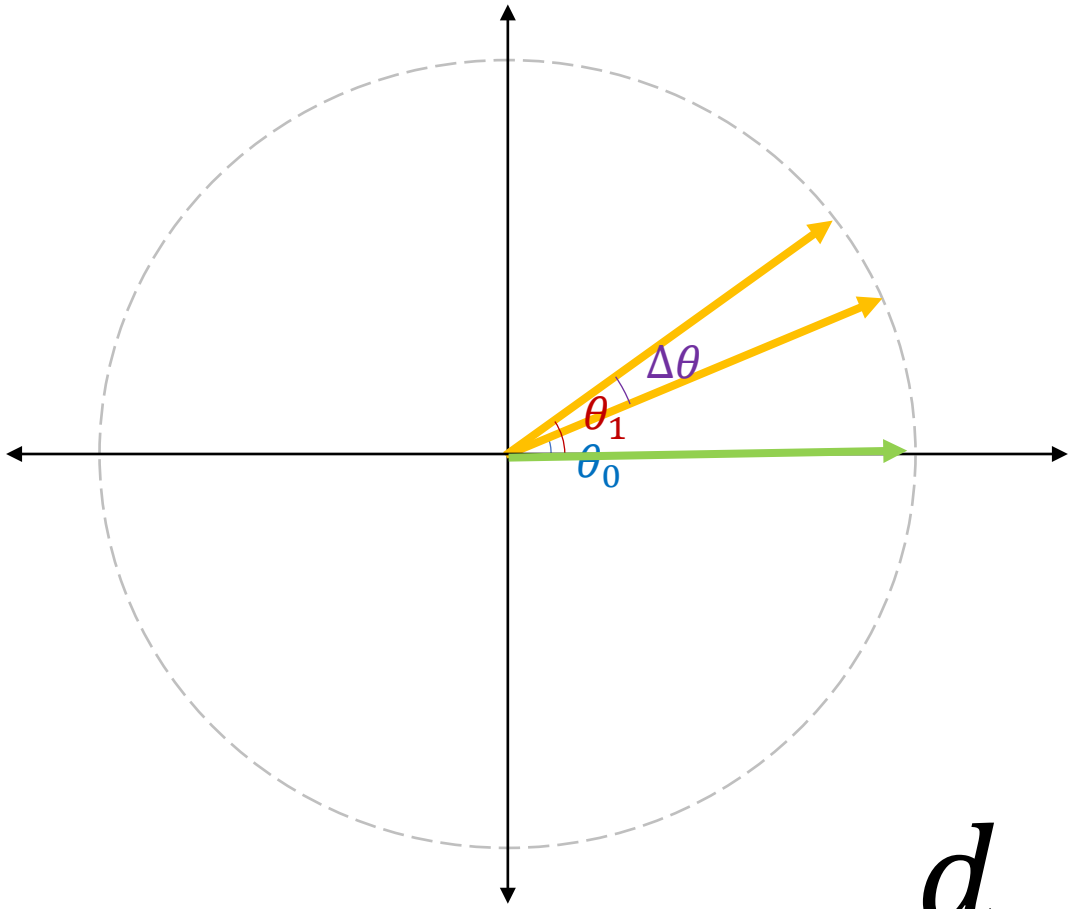
# Relation Between Phase Angle and Frequency

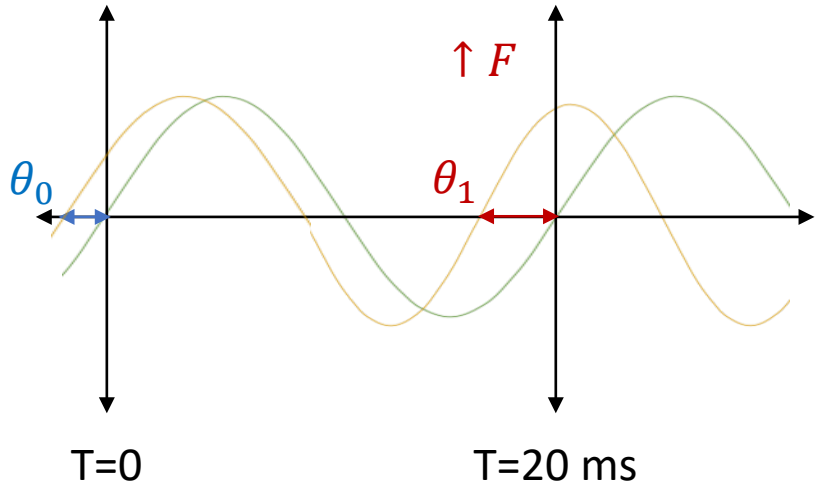



Measuring rate: 50 Hz

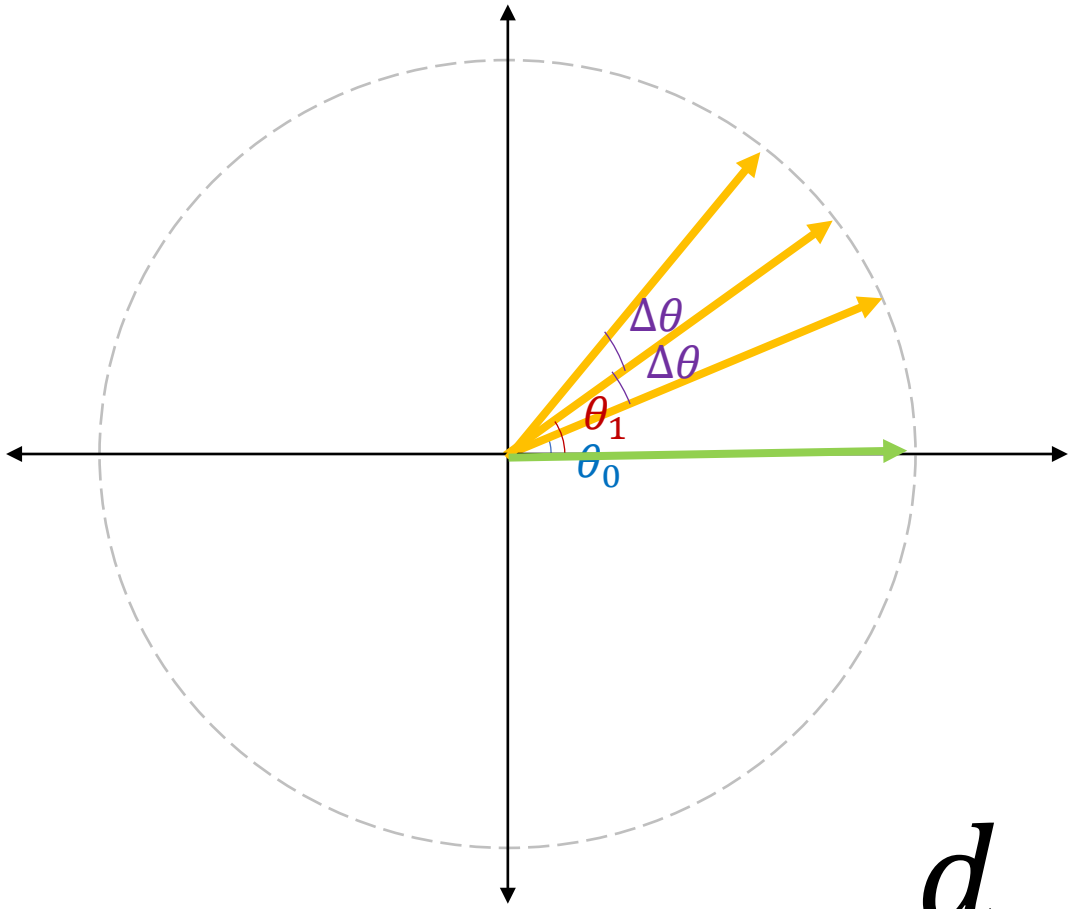
# Relation Between Phase Angle and Frequency

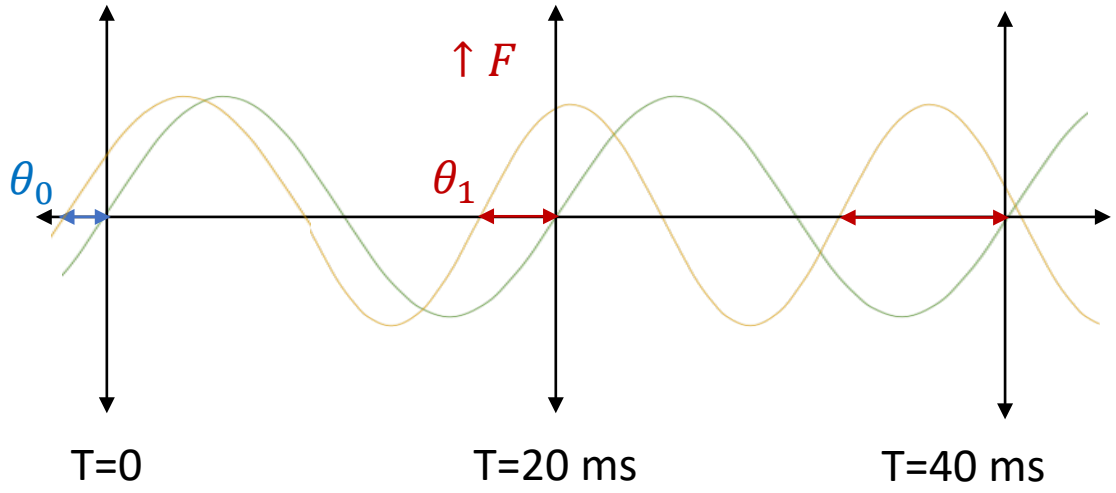



$$\frac{d}{dt}\Delta\theta \propto \Delta f$$

# Relation between Phase Angle and Frequency



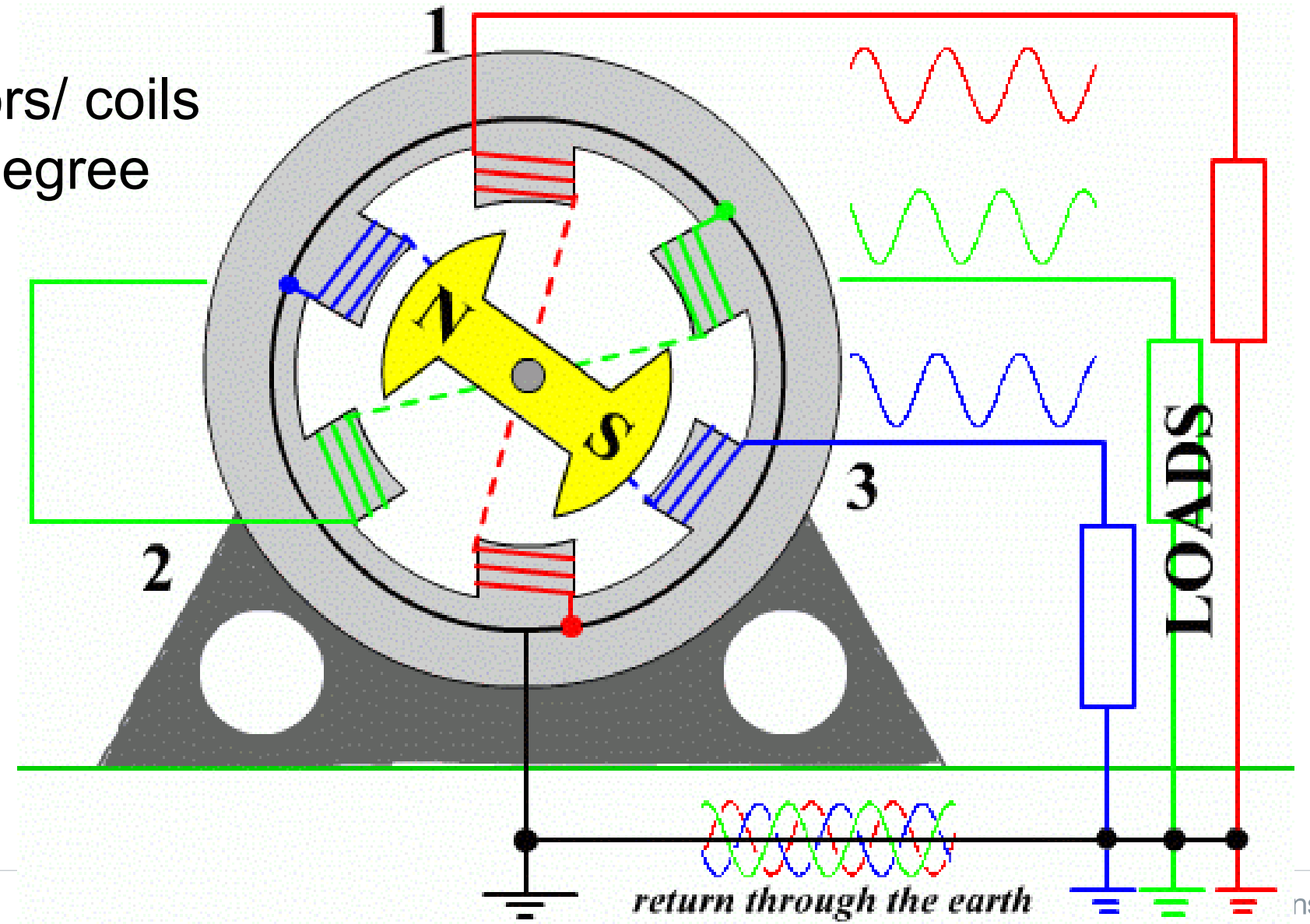




$$\frac{d}{dt}\Delta\theta \propto \Delta f$$

# 3-phase synchronous generator

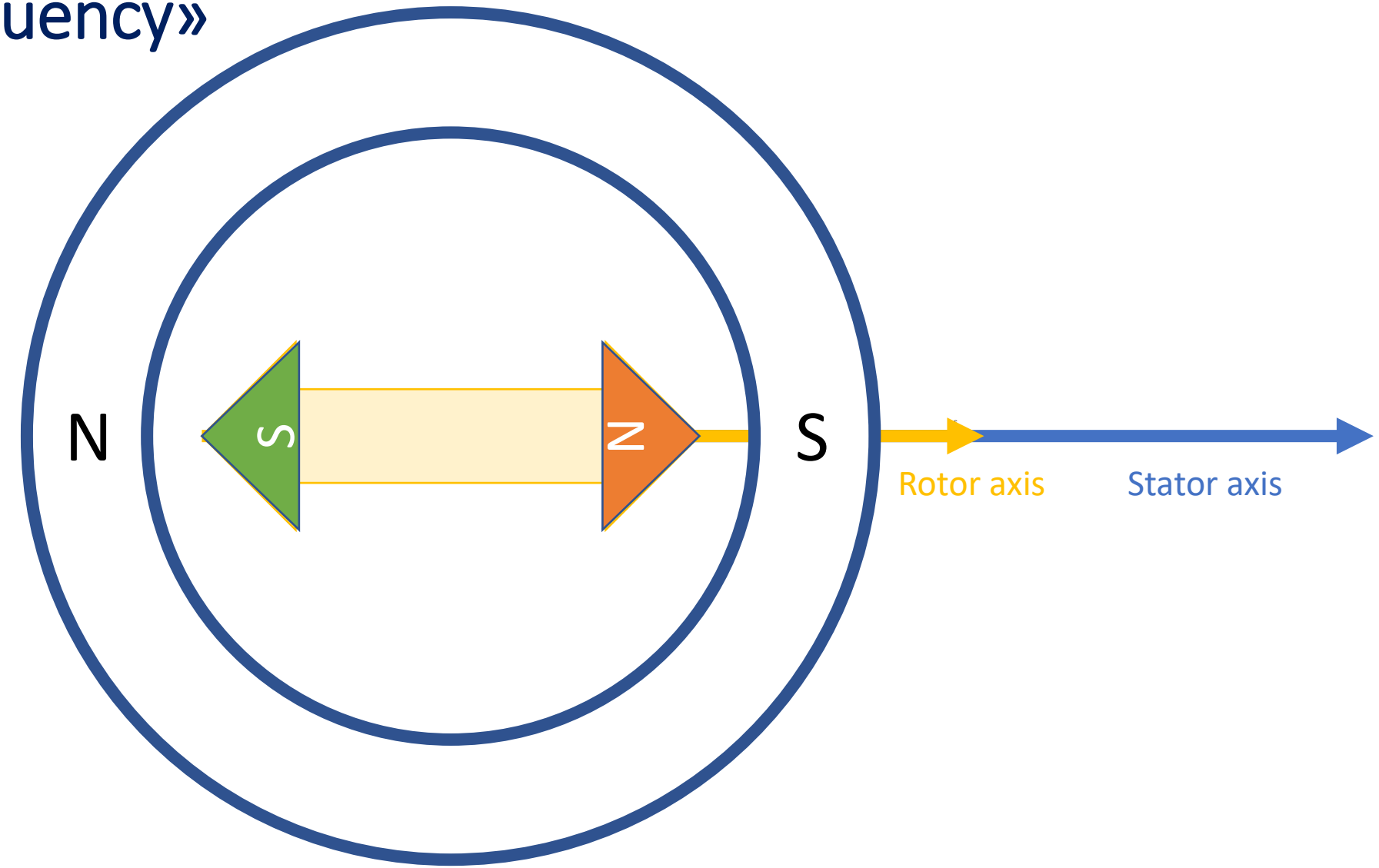
3 different inductors/ coils arranged at 120 degree difference

3 sinusoidal voltages are induced

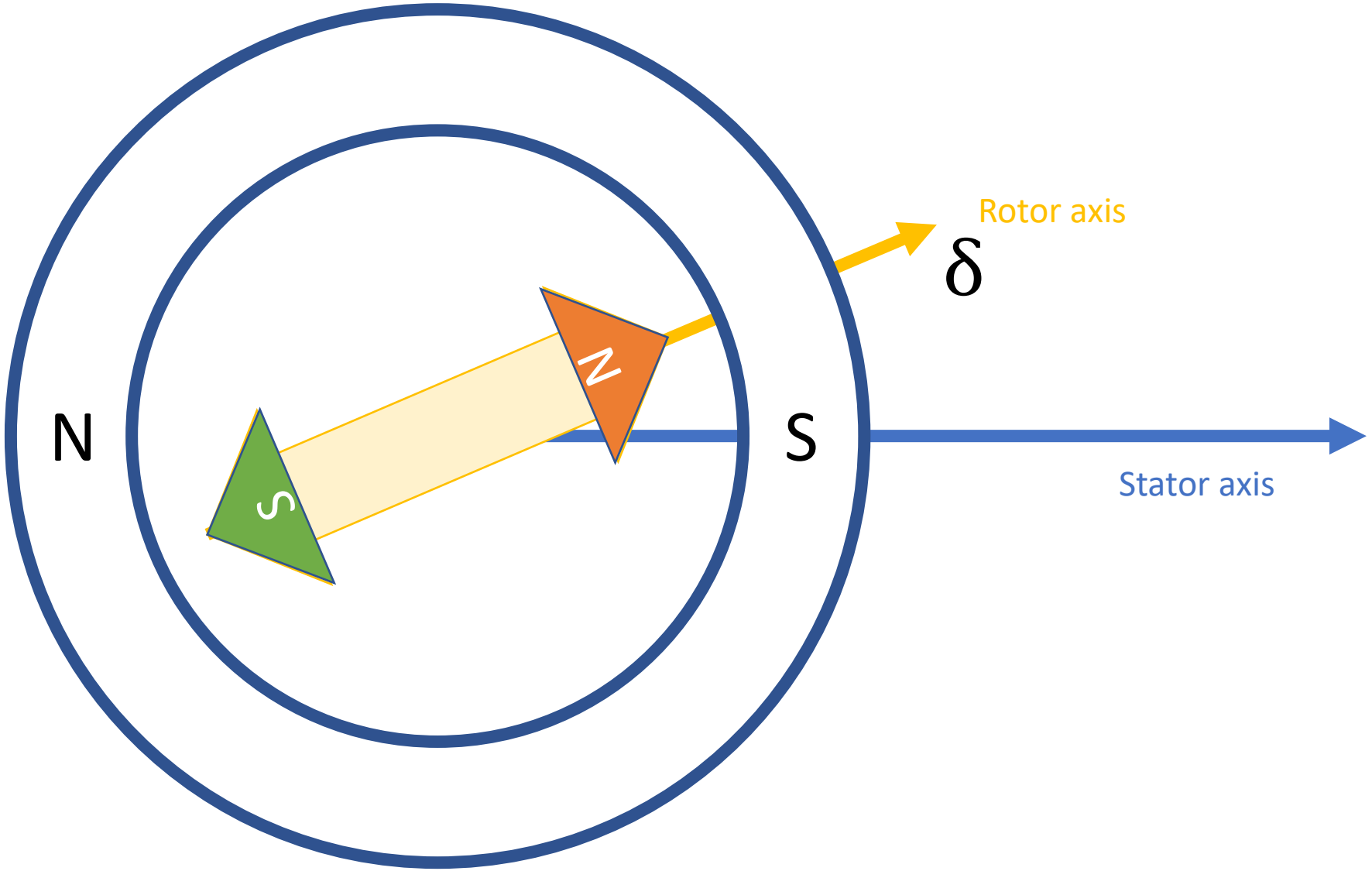



Source: Quora

# Synchronous machine: Rotor speed «follows» stator voltage frequency»



# Electric power depends on rotor angle



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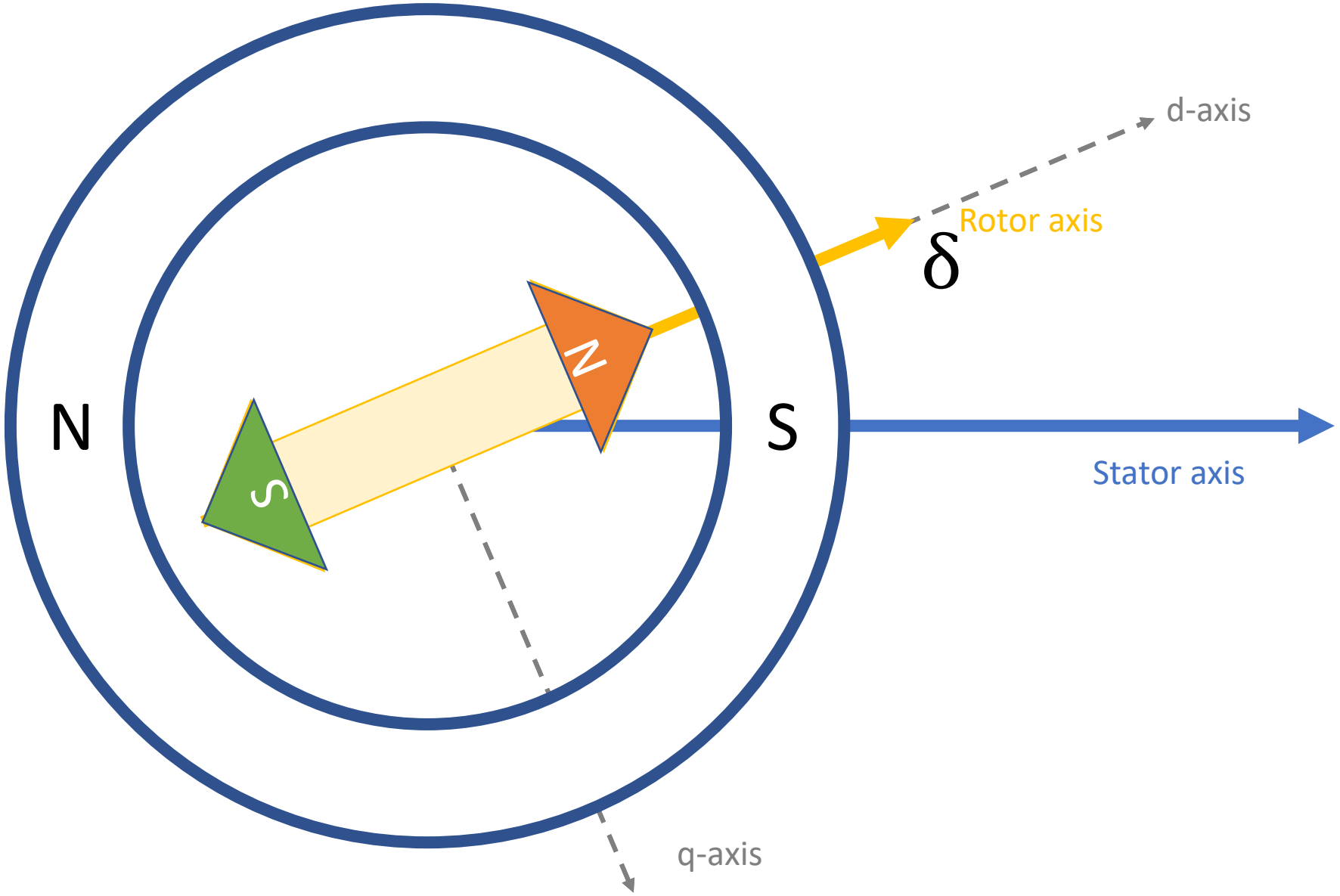
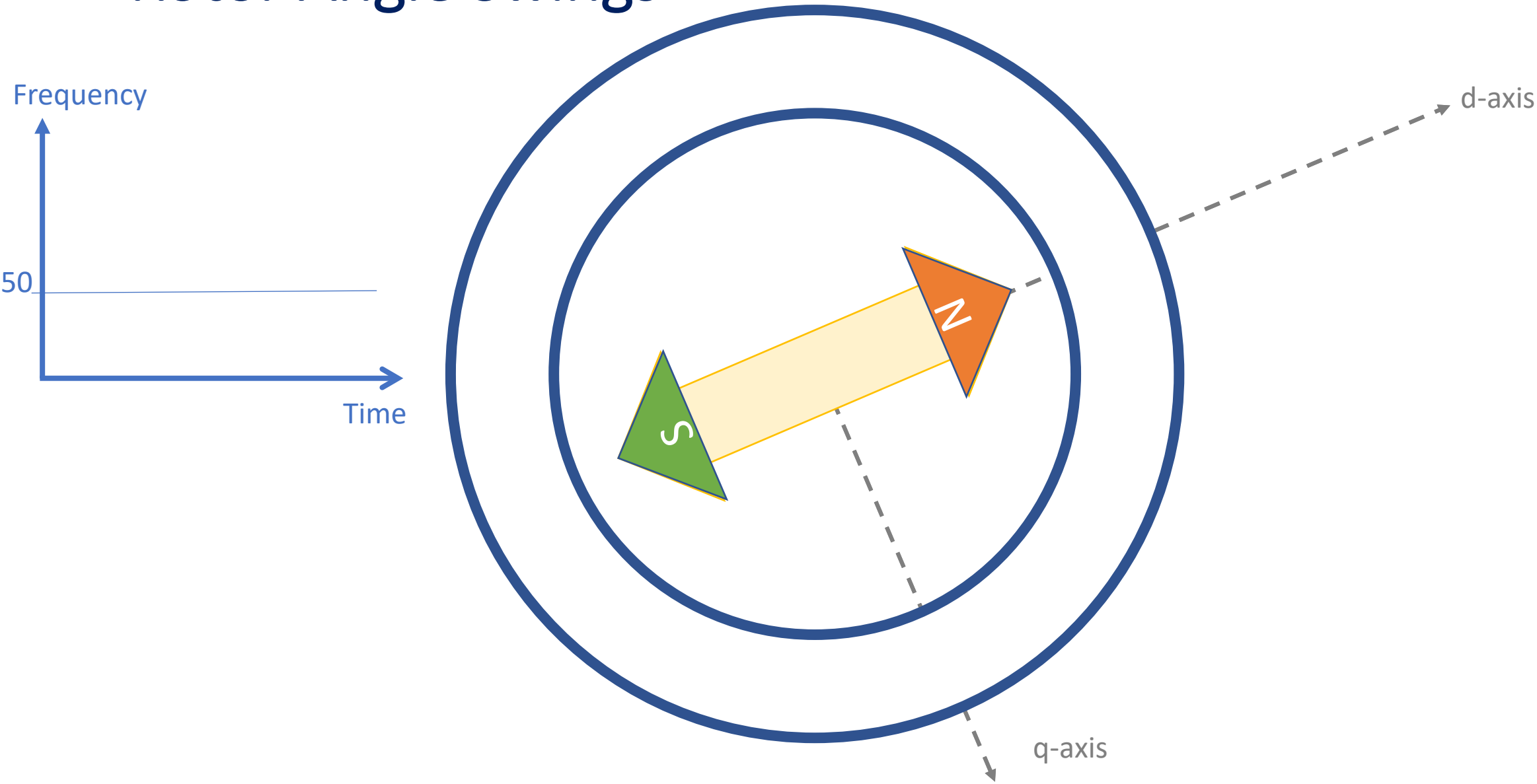
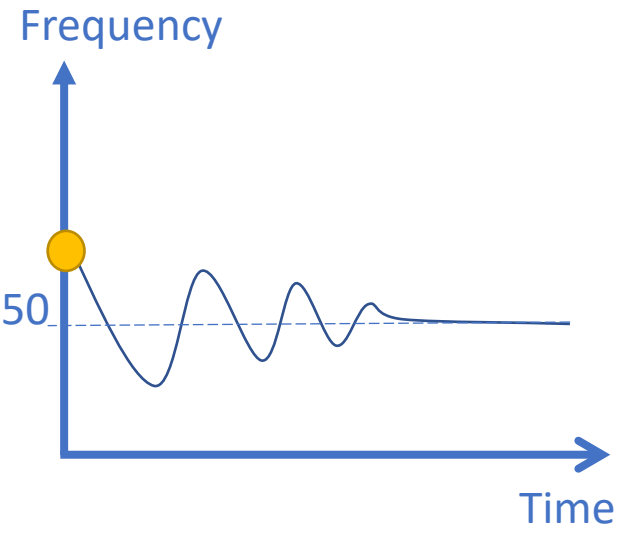
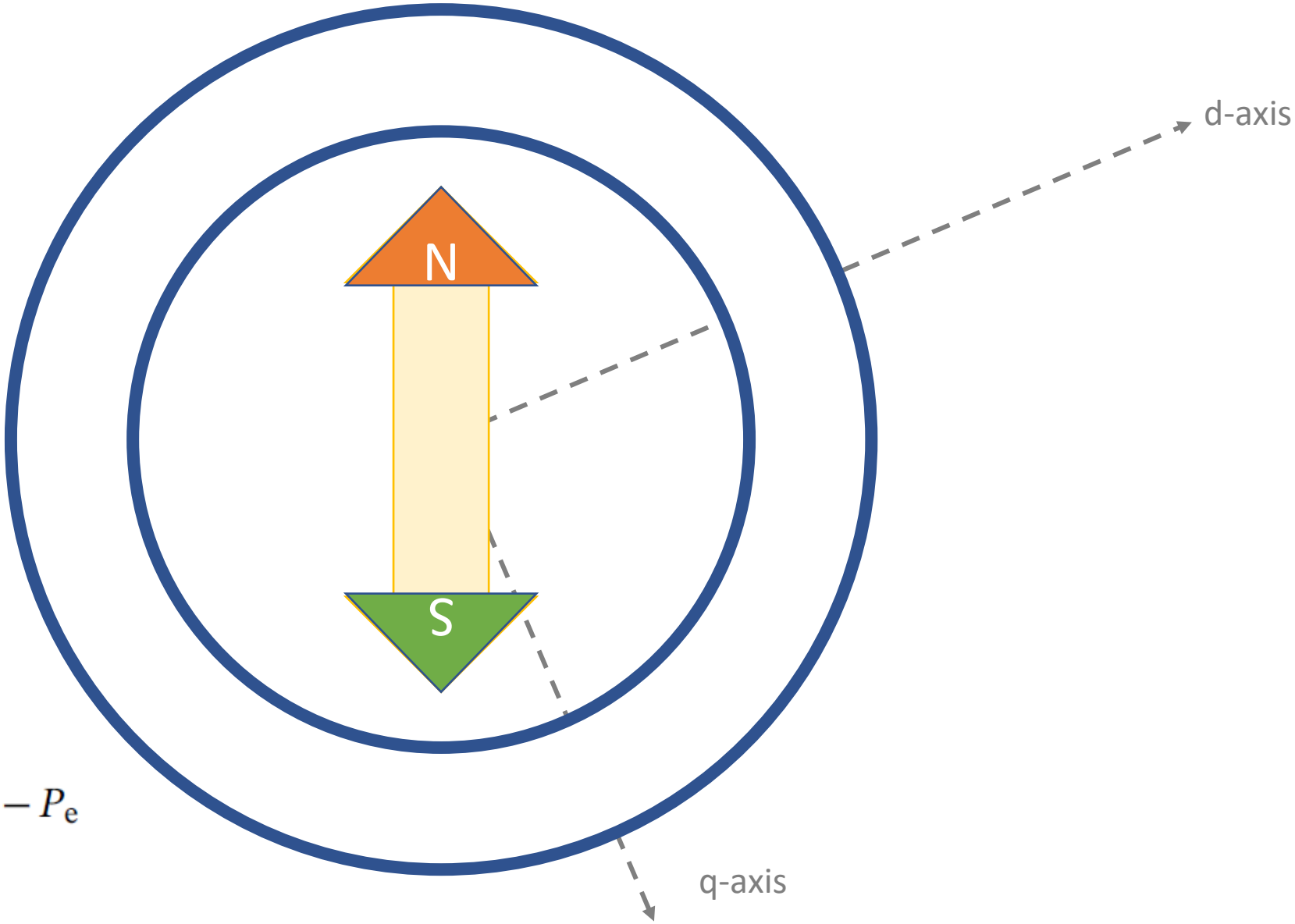


# Rotor Angle Swings



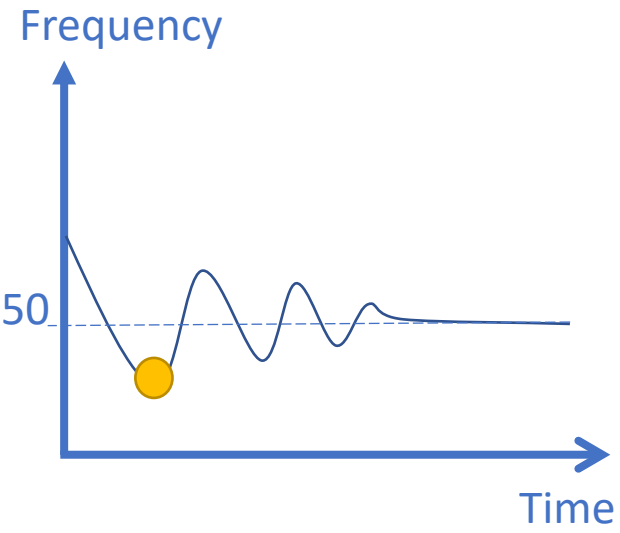
# Rotor Angle Swings → power oscillations

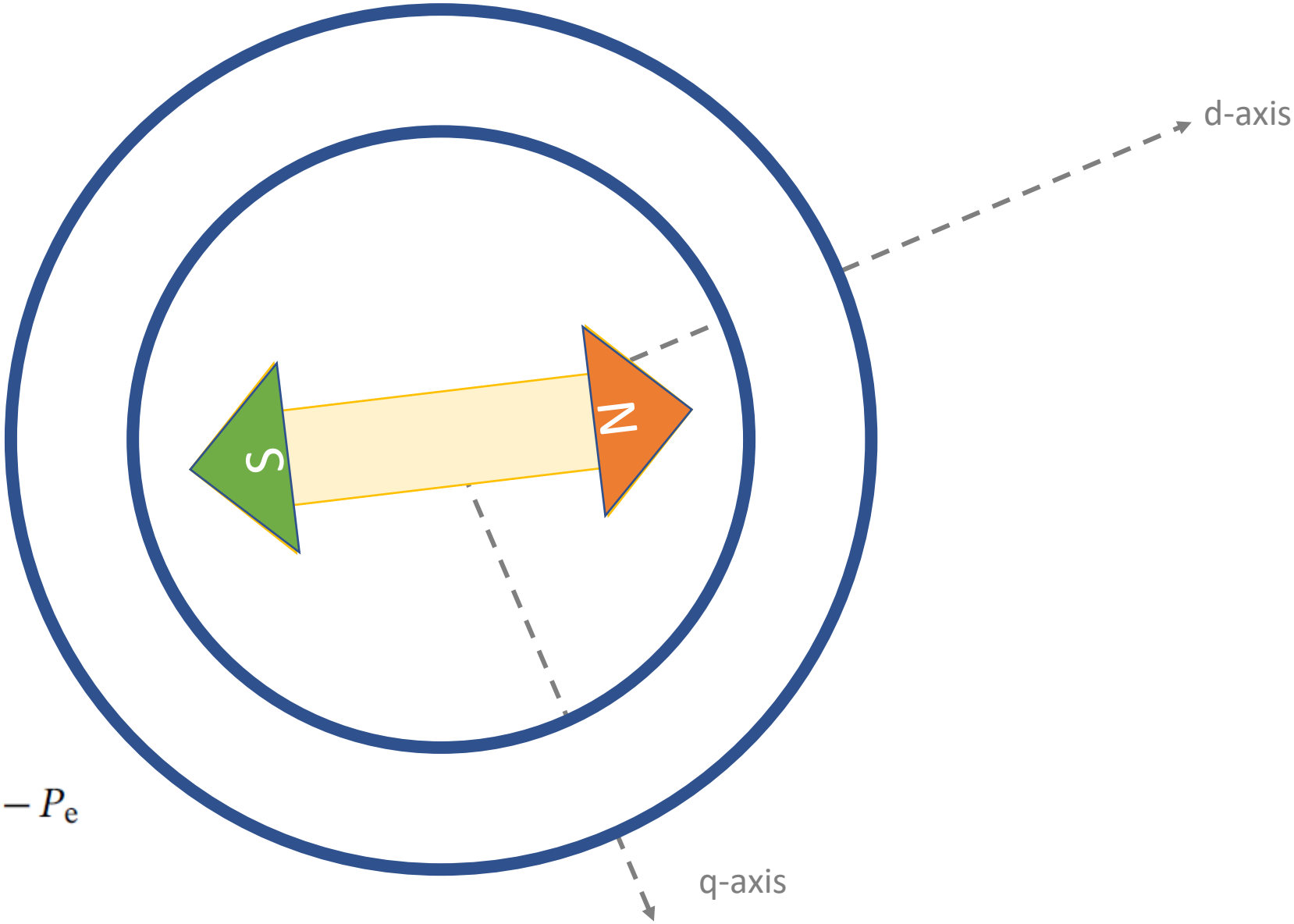



$$\frac{2HS_n}{\omega_s}\frac{d^2\delta}{dt^2} + D\frac{d\delta}{dt} = P_m - P_e$$

# Rotor Angle Swings → power oscillations → frequency variations

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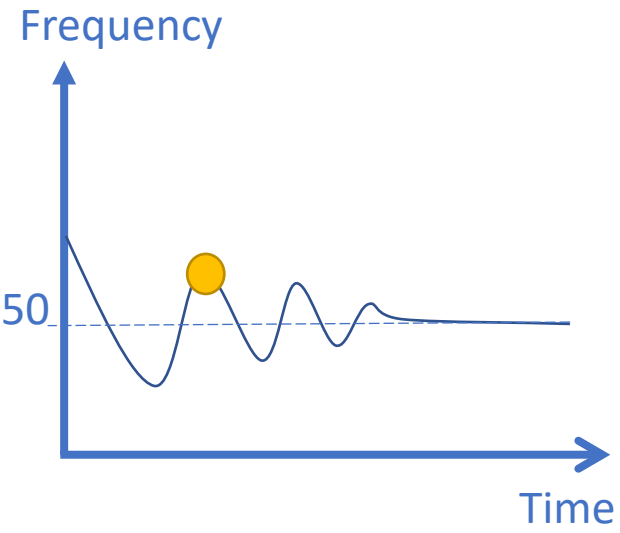


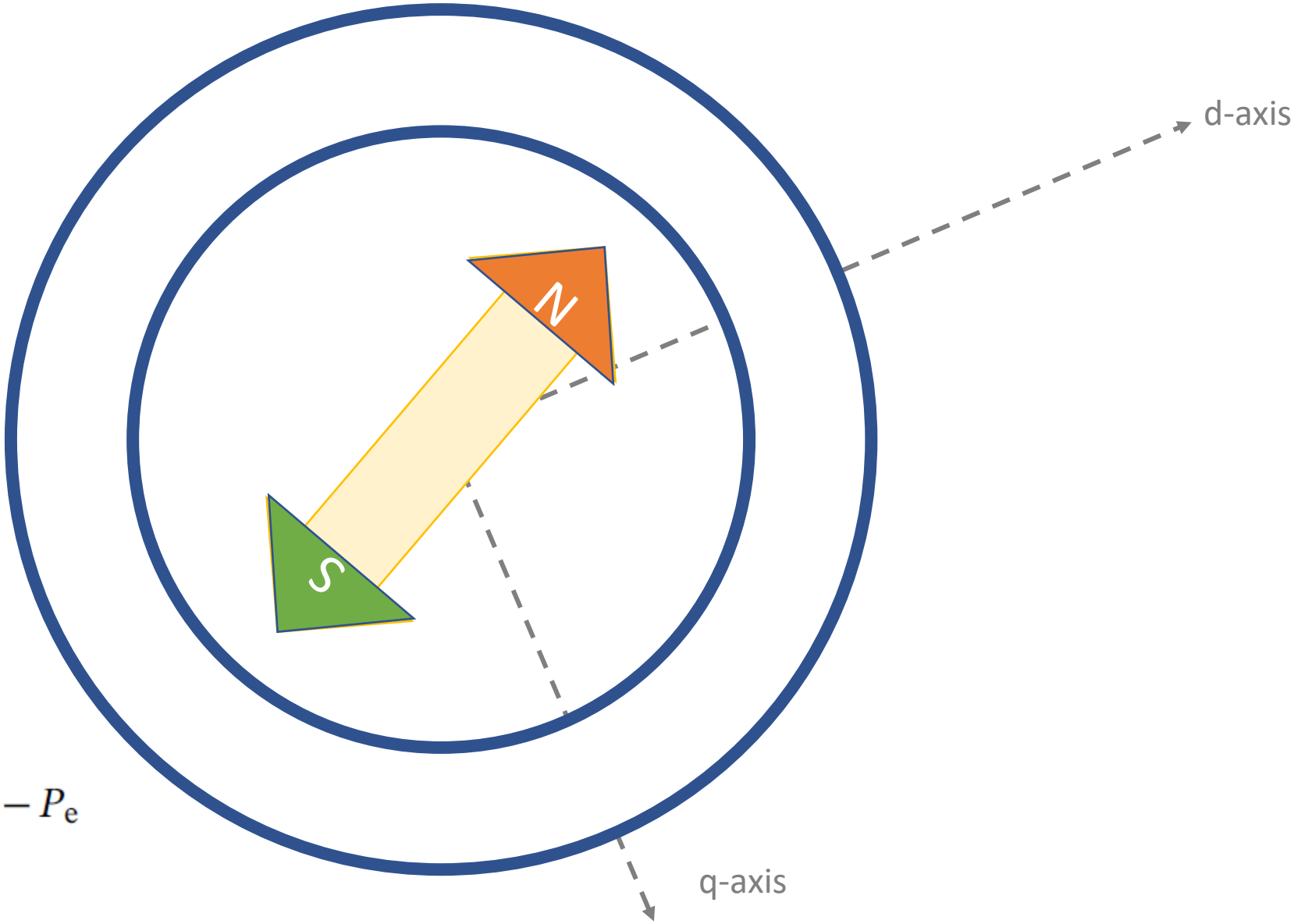


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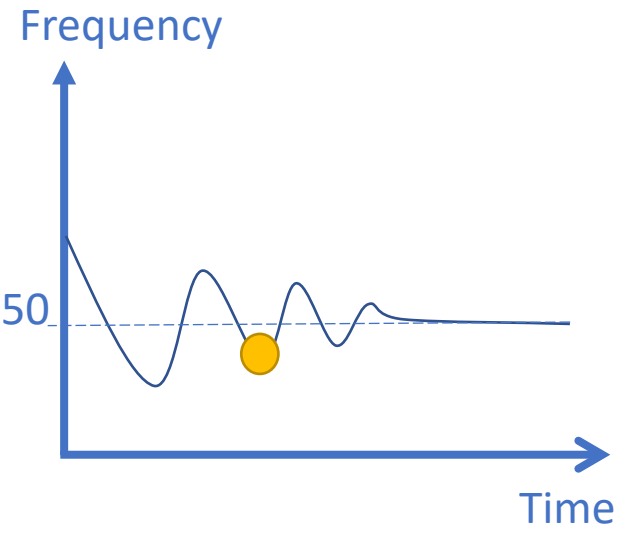


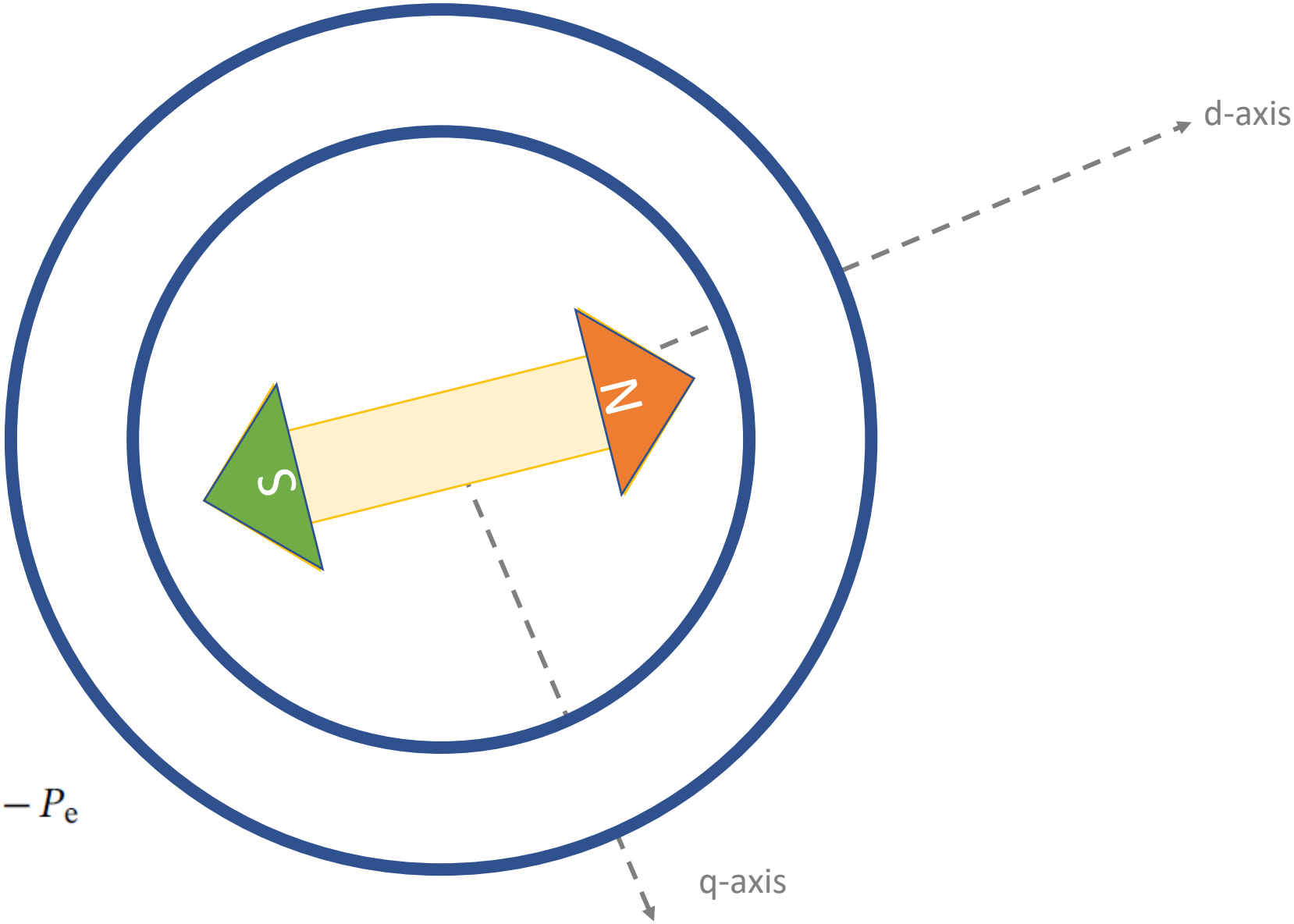


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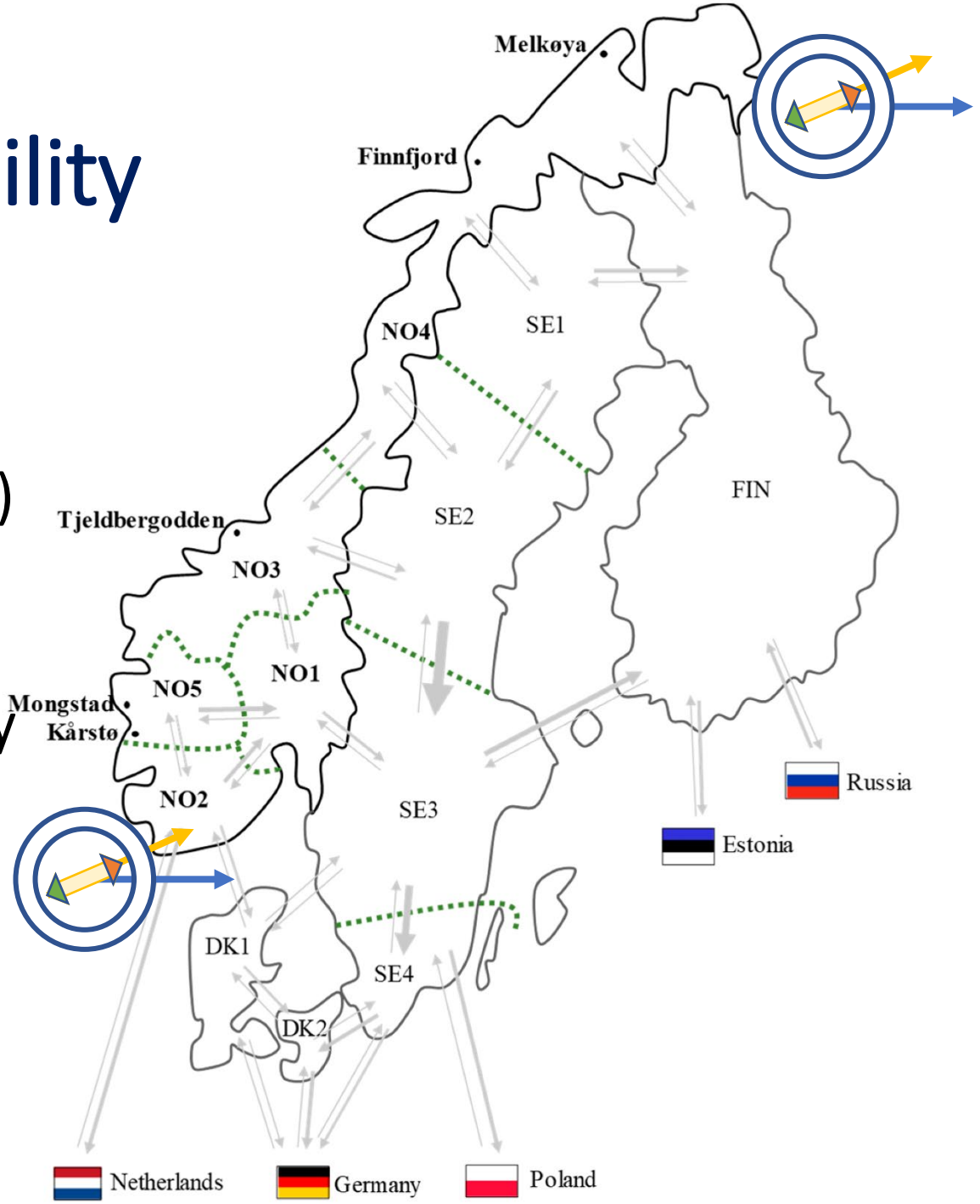
# System stability

- Low frequency system wide modes (0.1-1 Hz) exist
- Important stability property is damping of such modes



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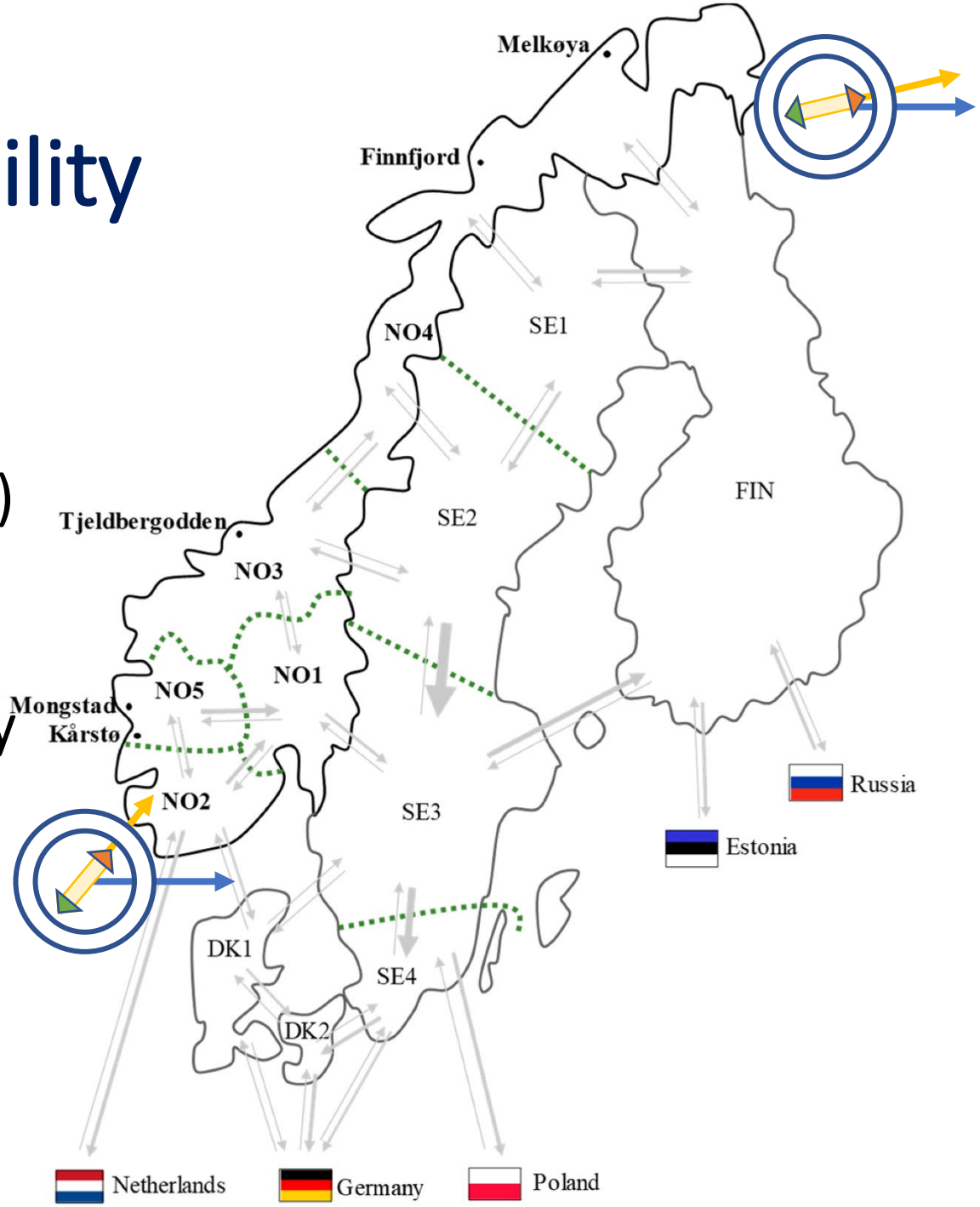

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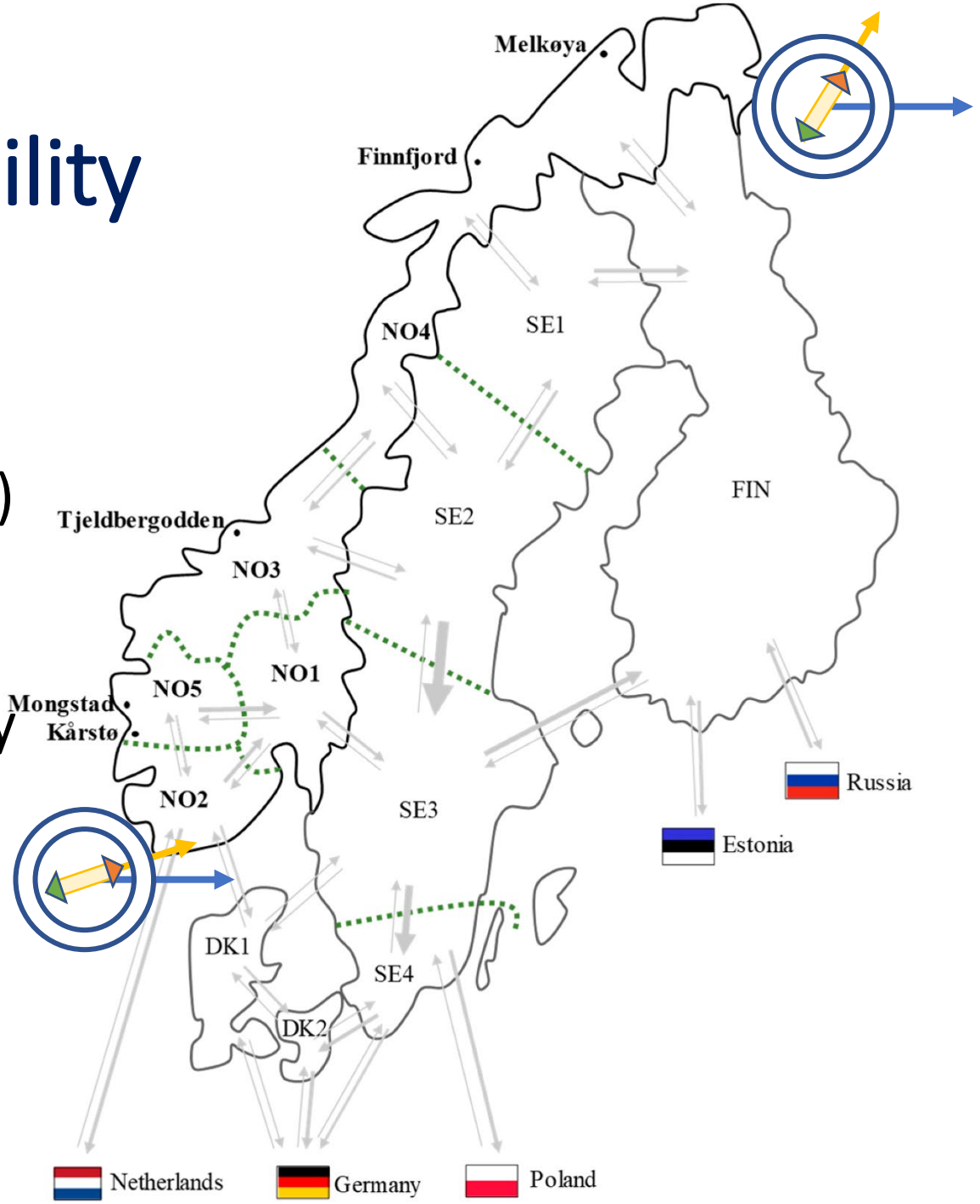

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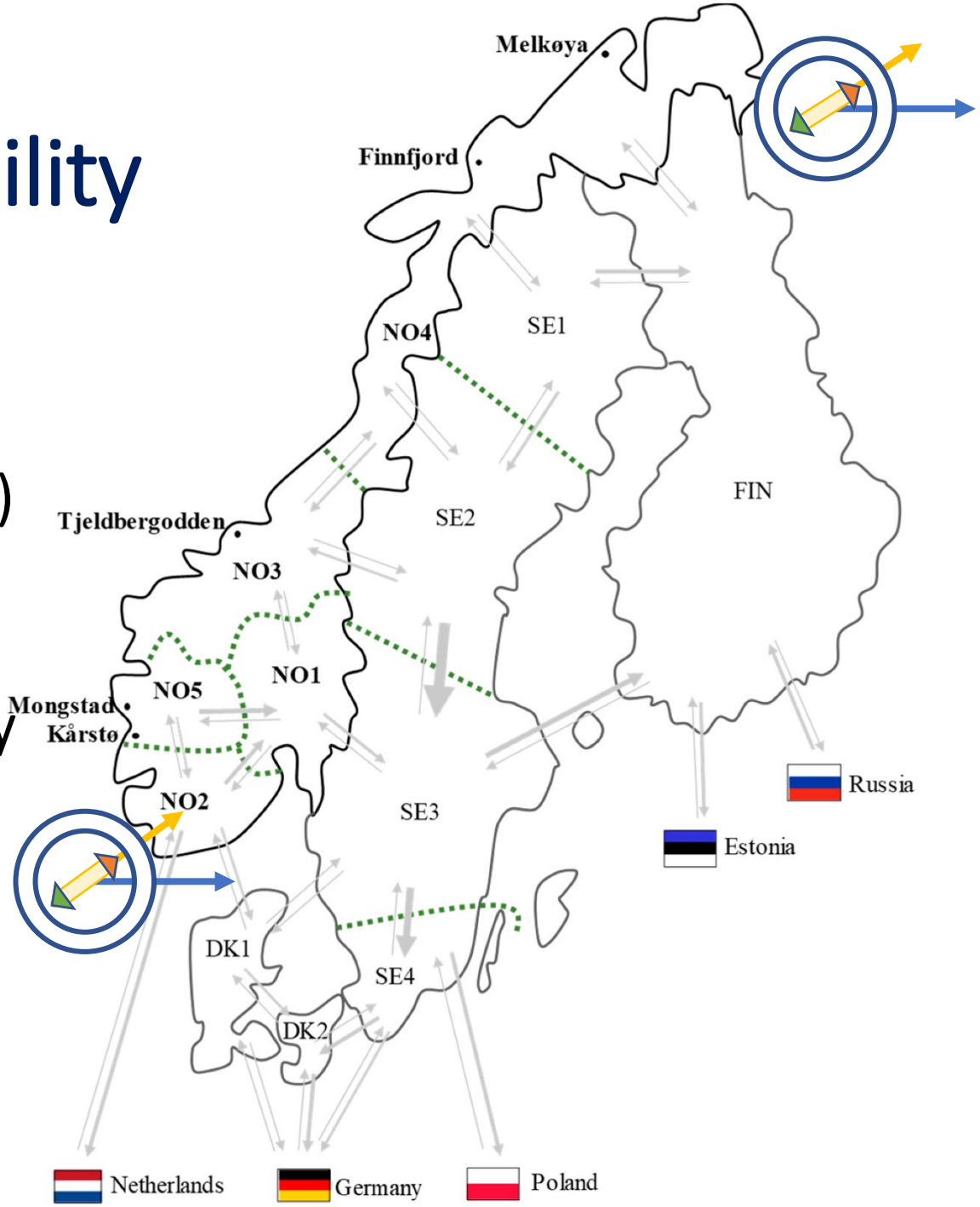


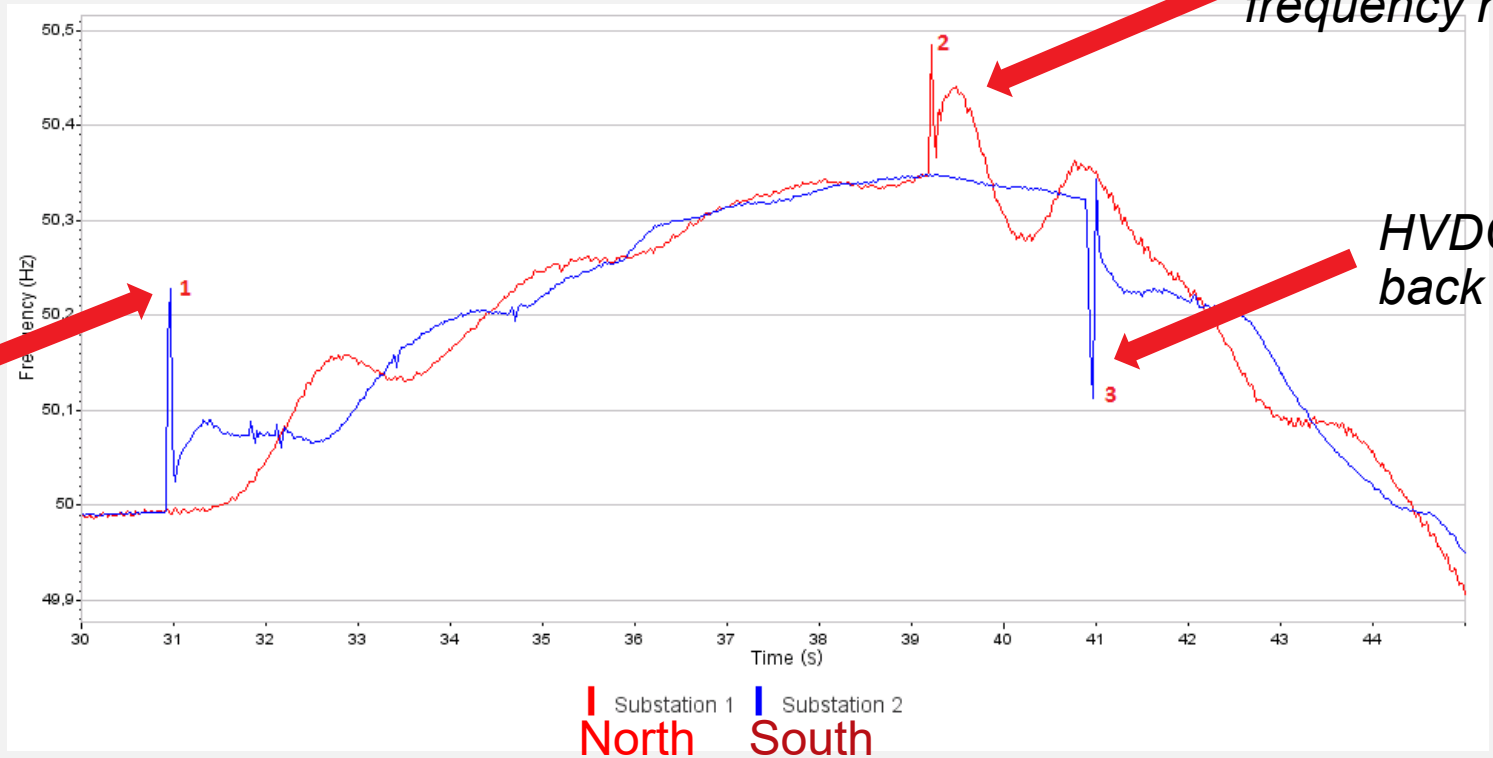
Example

# Wide Area Monitoring – seeing the whole picture

*Load trips due to high frequency north in Norway*

*HVDC ramps back to full export*

*Trip of HVDC south in Norway*




*15 seconds of frequency variations – current SCADA system is neither showing nor connecting the dots*

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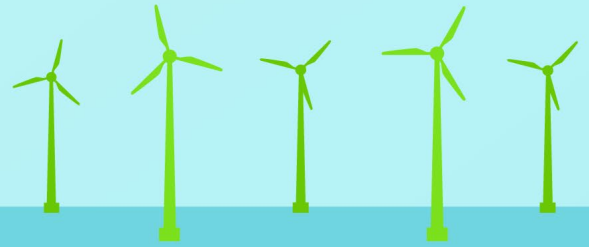


# NEWEPS – who and what

Statnett

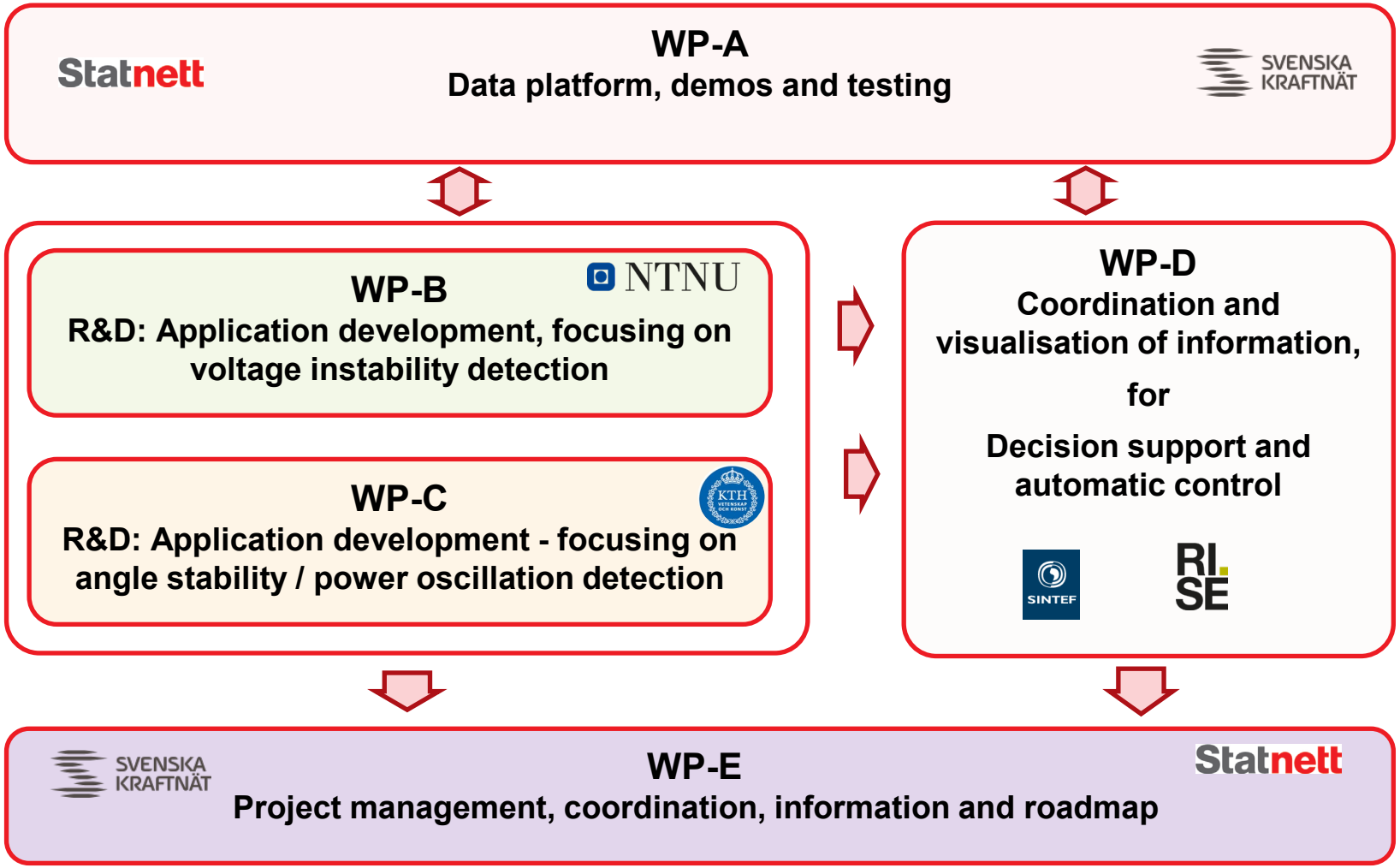
SVENSKA KRAFTNÄT

NTNU

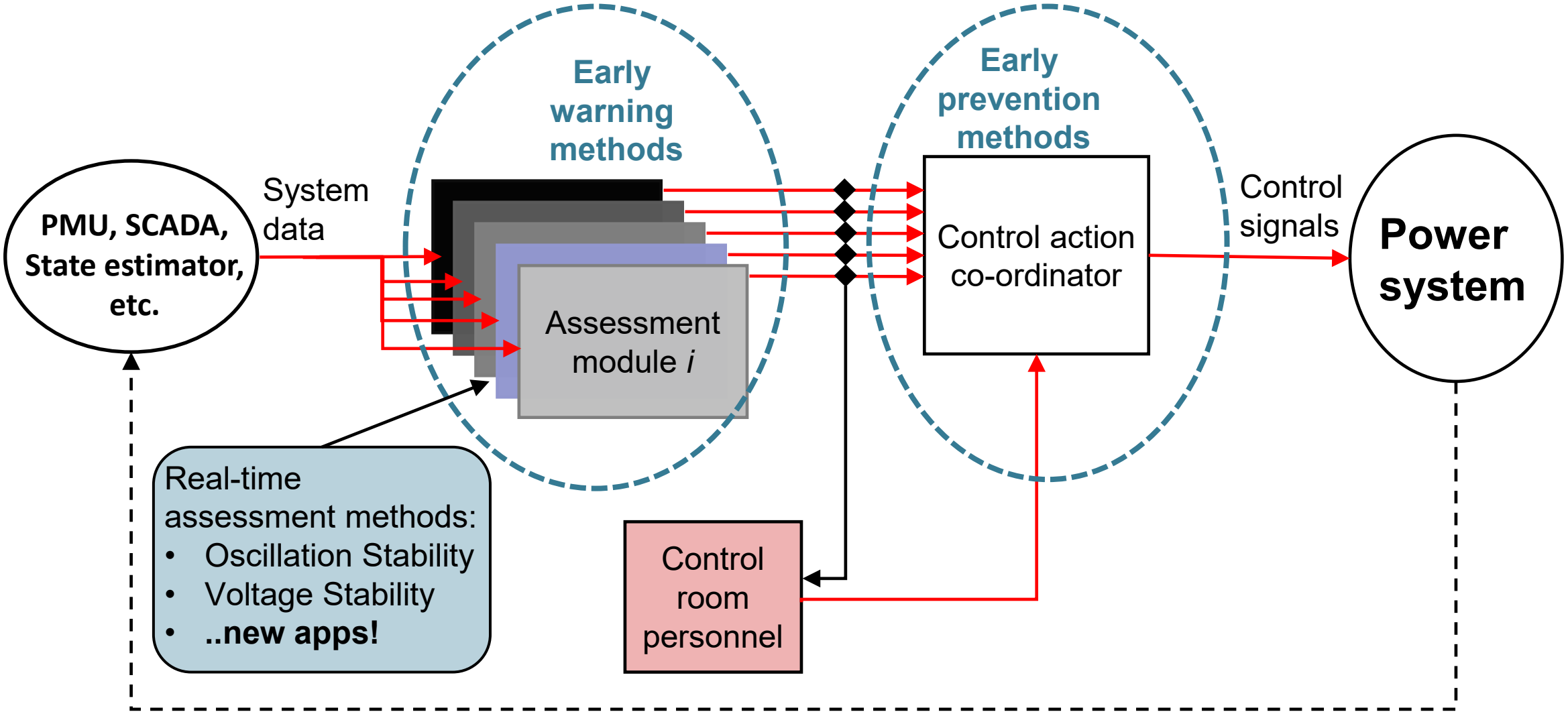
KTH VETENSKAP OCH KONST

SINTEF

RI. SE



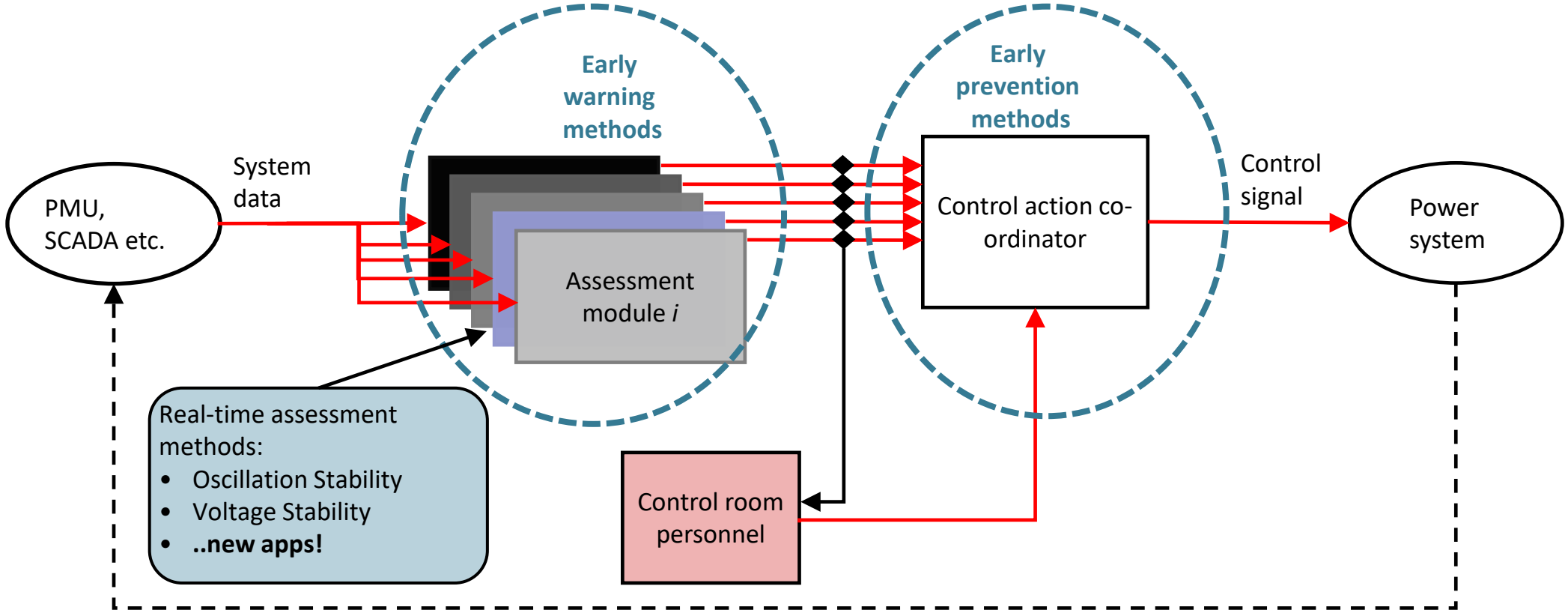
# NEWEPS – The concept



Nordic (System)

# N - NORDIC

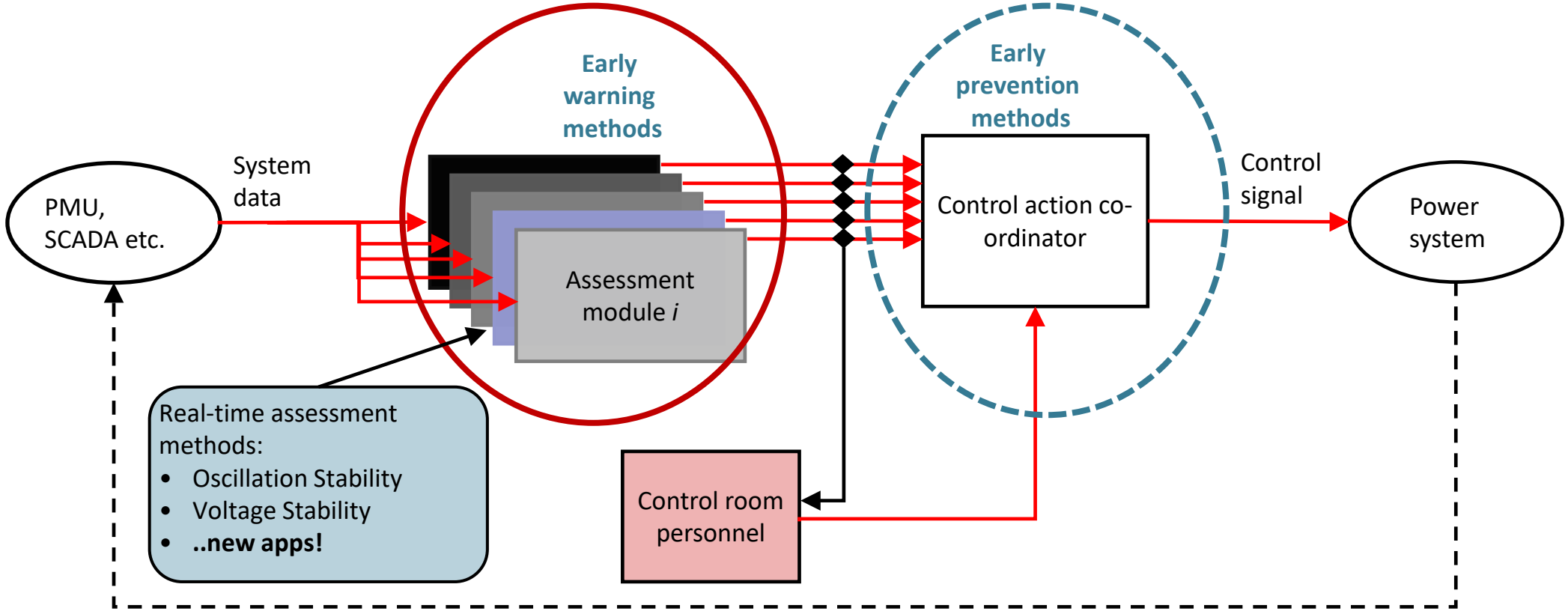
- Nordic synchronized power grid
- Integrated market, sharing of reserves and coordination of controls
- Situational awareness needs to be on the Nordic level



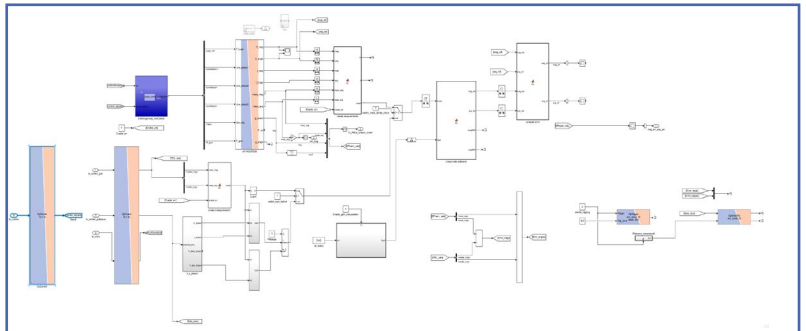
# EW – Early Warning



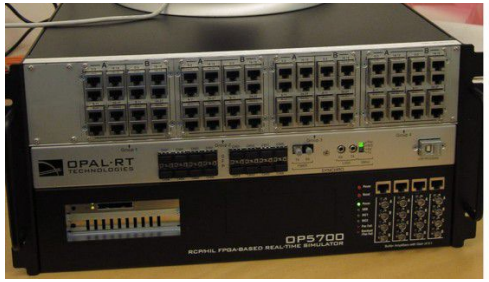
- Development of  methods and algorithms for early detection of critical operating situations, focusing on voltage and angle stability problems
- Testing in laboratory environment



# Laboratory testing and demonstration



Real-Time simulator

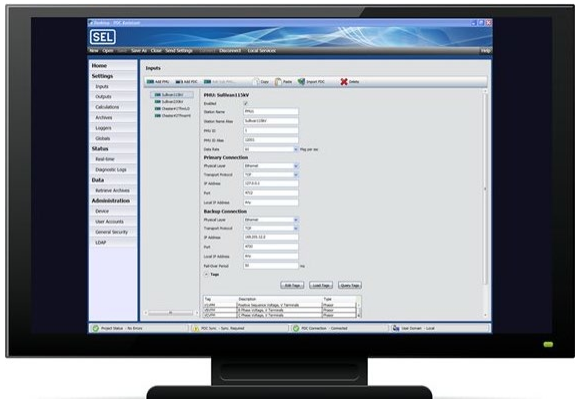



N44 in Opal-RT


Network box

Real-Time simulator

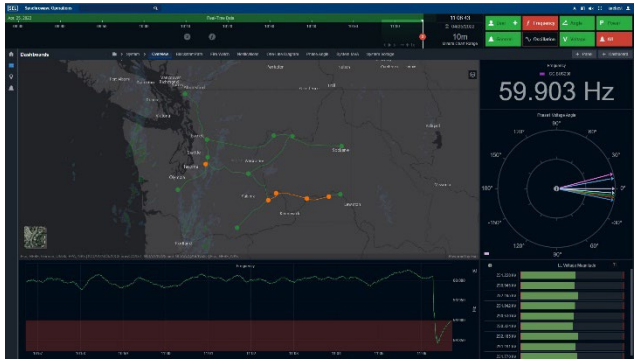
PMU streams



PDC

Synchrowave Operations

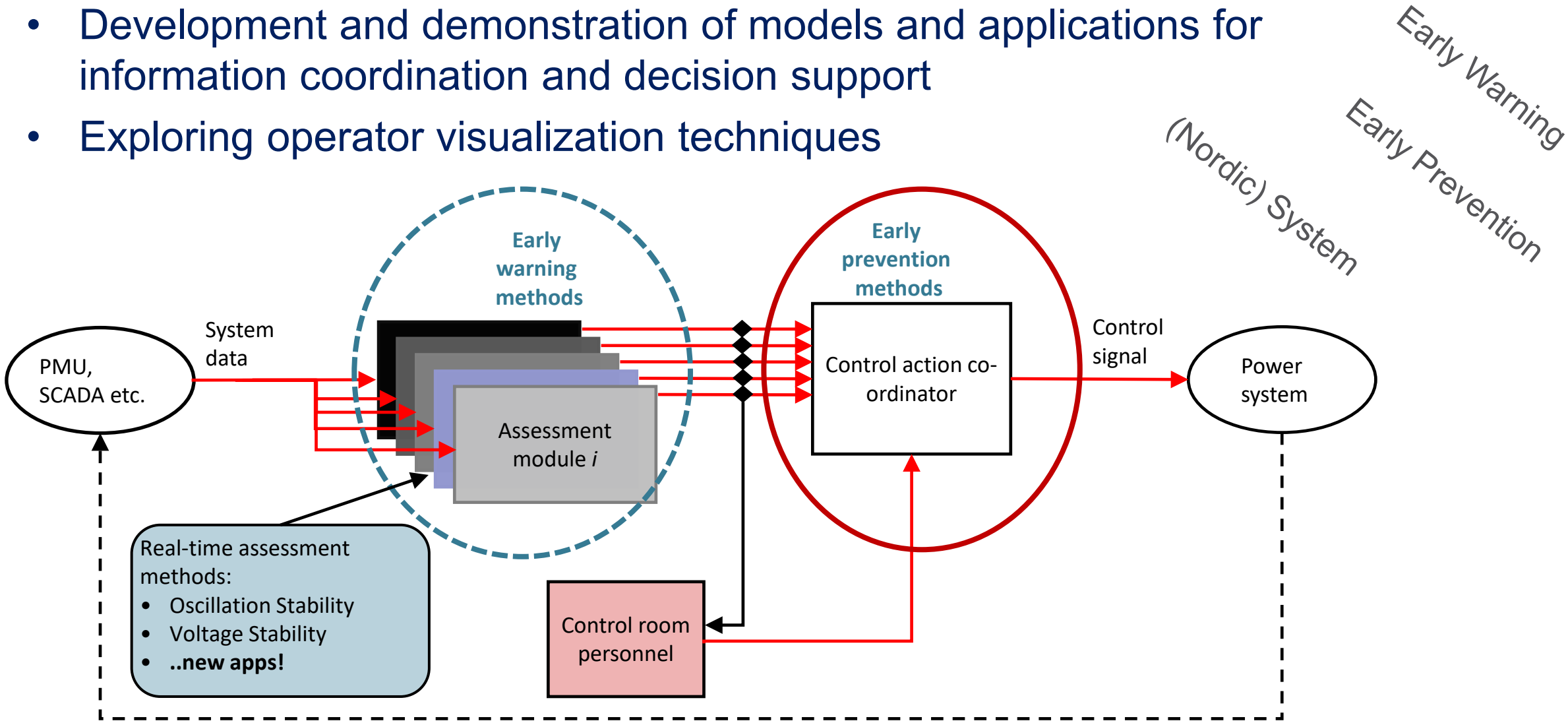
Control room




WAMS Platform

# EP – Early Prevention

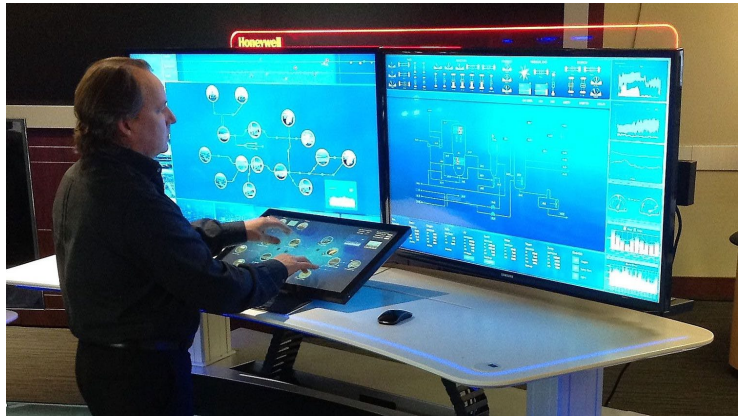
- Development and demonstration of models and applications for information coordination and decision support
- Exploring operator visualization techniques



# Visualizing power system operation

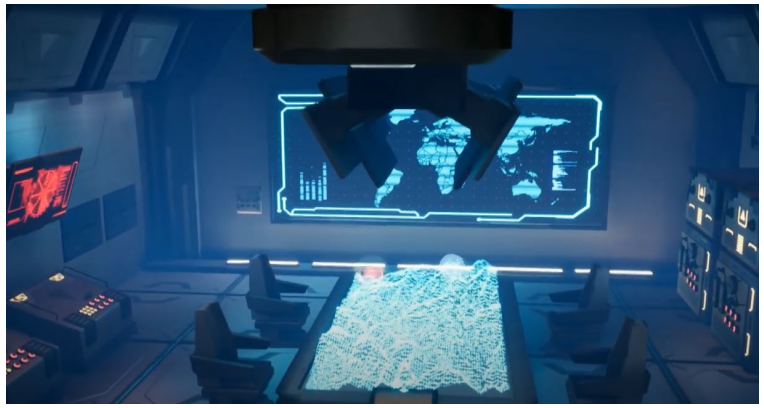
## How will the Future Control Room look like?

### Touch screen

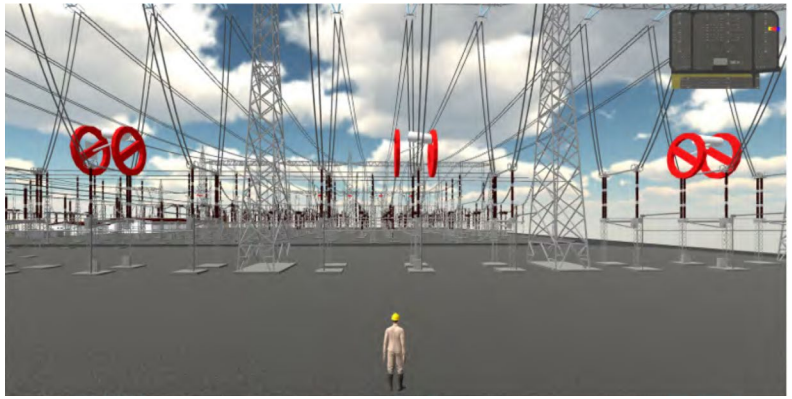




### Augmented reality/holograms



### Digital twin

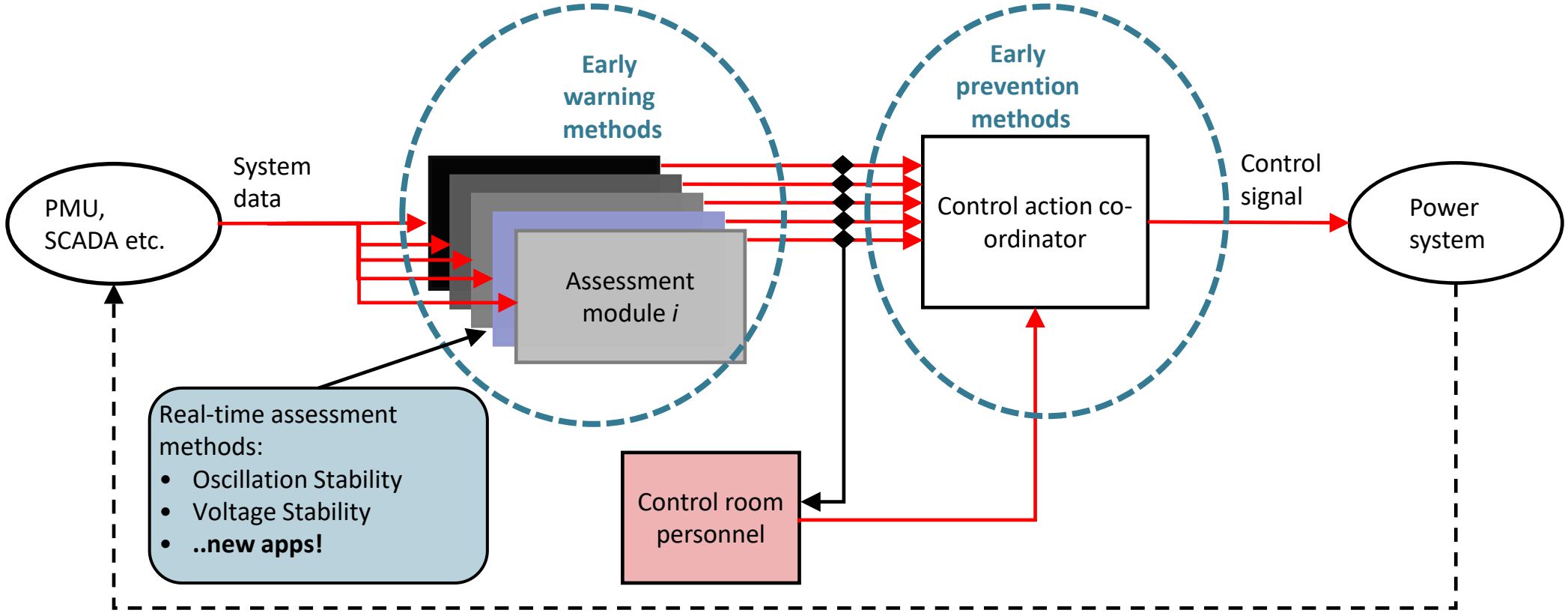


- **Existing Techniques**
  - Map Based, 2D, 3D
  - Spatio-temporal
- **Future Techniques**
  - Holograms
  - Touch screens
  - Augmented Reality

(Nordic) System

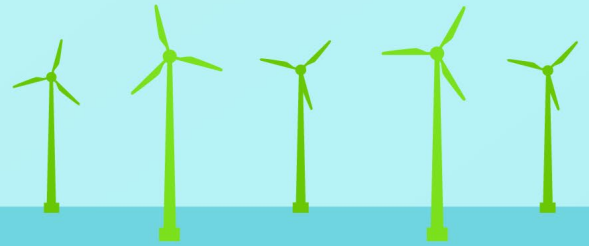
# S - System

- Building an IT-platform for prototype testing of selected applications
- (At this stage) not fully integrated in the operational environment
- .. But enabling strong involvement by operators



# Outline

- Introduction - What is NEWEPS about?
- Phasors and Phasor Measurements
- NEWEPS project - plans and ambitions
  - N – Nordic
  - EW – Early Warning
  - EP – Early Prevention
  - S - System
- Expected results and way forward



# Expected results and way forward

- New and improved stability monitoring applications (building upon earlier results and state-of-the-art research)
- Tested and validated in laboratory environment
- Research and demonstration of methods for Visualization and Coordination of critical information
- IT-platform enabling prototype testing with strong user (operator) involvement
- Roadmap towards realisation of next generation (modular ) control centre solutions

# How do we develop the next generation control centres and automatic controls for the power systems?

Statnett

# Thank you!