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Session 2:
Synchrophasors for System Protection

Kjetil Uhlen,
NTNU, Electrical Engineering
kjetil.uhlen@ntnu.no

NTNU
Norwegian University of Science and Technology

System Protection (SIPS, SPS, RAS, ..)

- Automatic controls (related to)
  - Emergency control
  - To reduce risk (consequences of failures)
  - Can be used to raise power transfer capacities
- Economic value can be very high!

System Protection

Controls:

- Load shedding
- Generator tripping
- Controlled islanding (network splitting)
- Switching (lines, capacitor banks, reactors)

System Protection

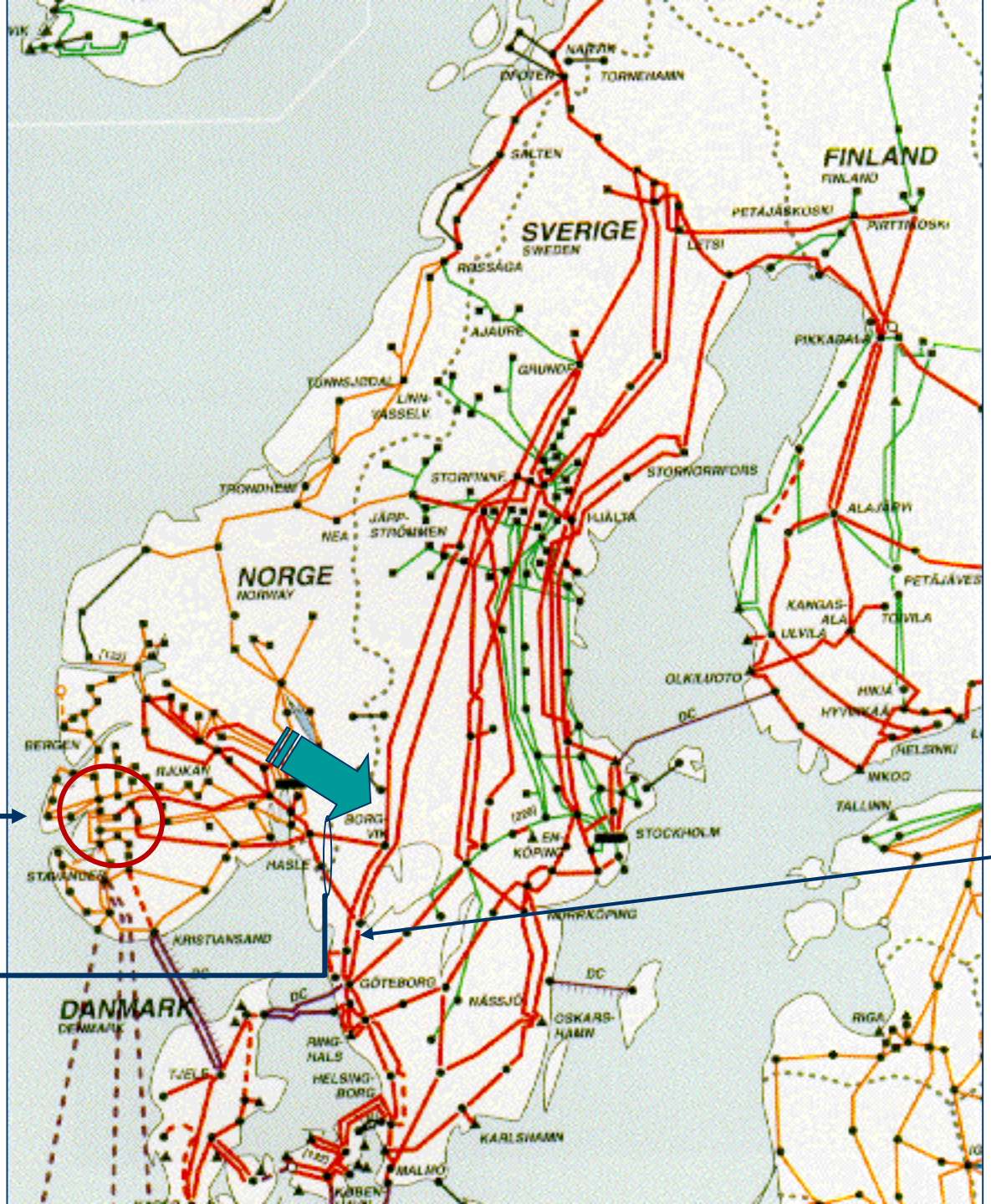
- Aims at protecting the system (not components)
- Design based on experience and knowledge about the system
- Difficult to verify the robustness (security/dependability) of SPs

Examples: Measurements from disturbances in the Nordic grid

- Generator tripping schemes are extensively used to raise power transfer capacity between Norway and Sweden.

- Secure and Dependable?
- Hidden failures in the design?

1. Secure?

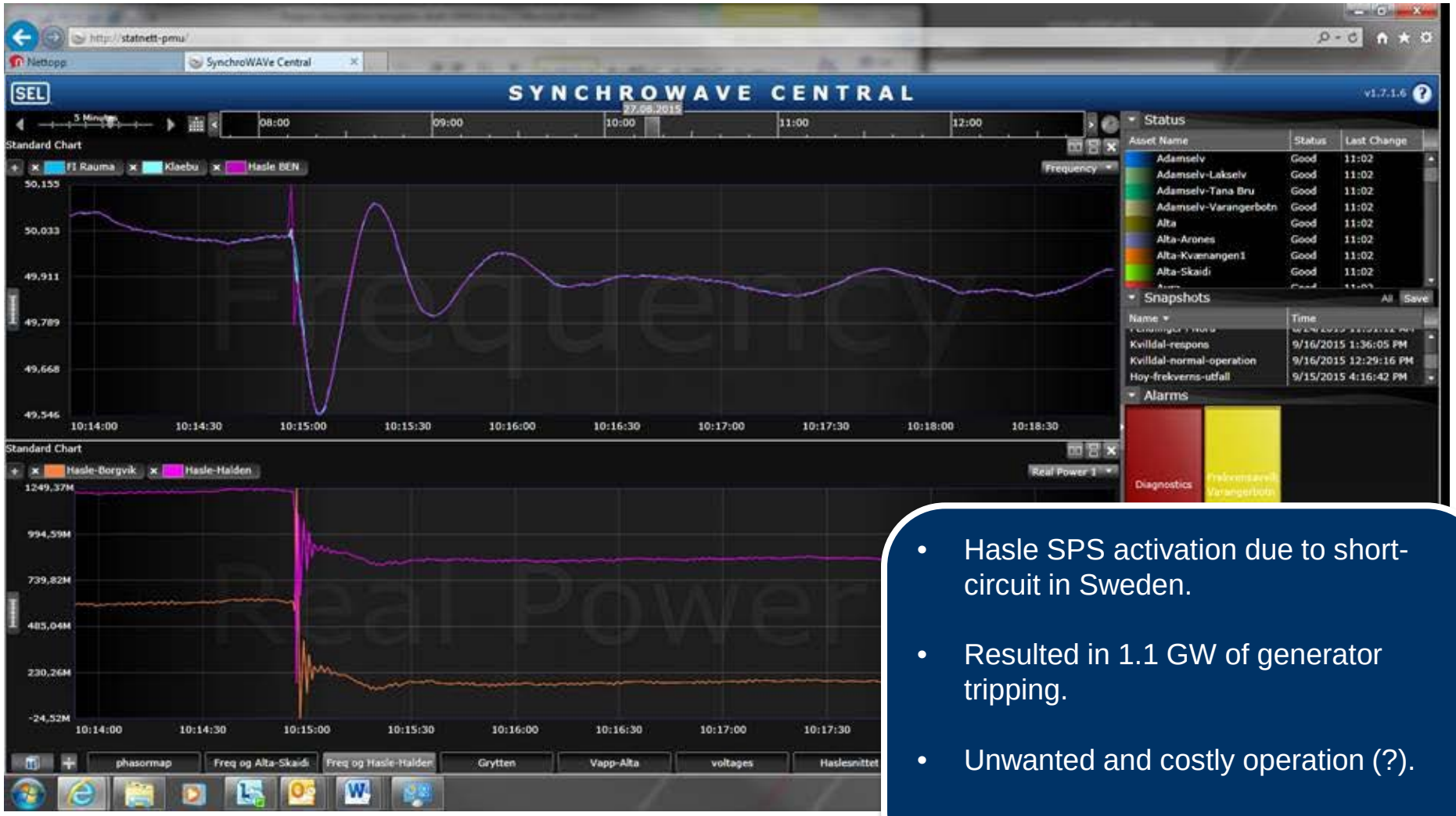


Generator tripping

SP

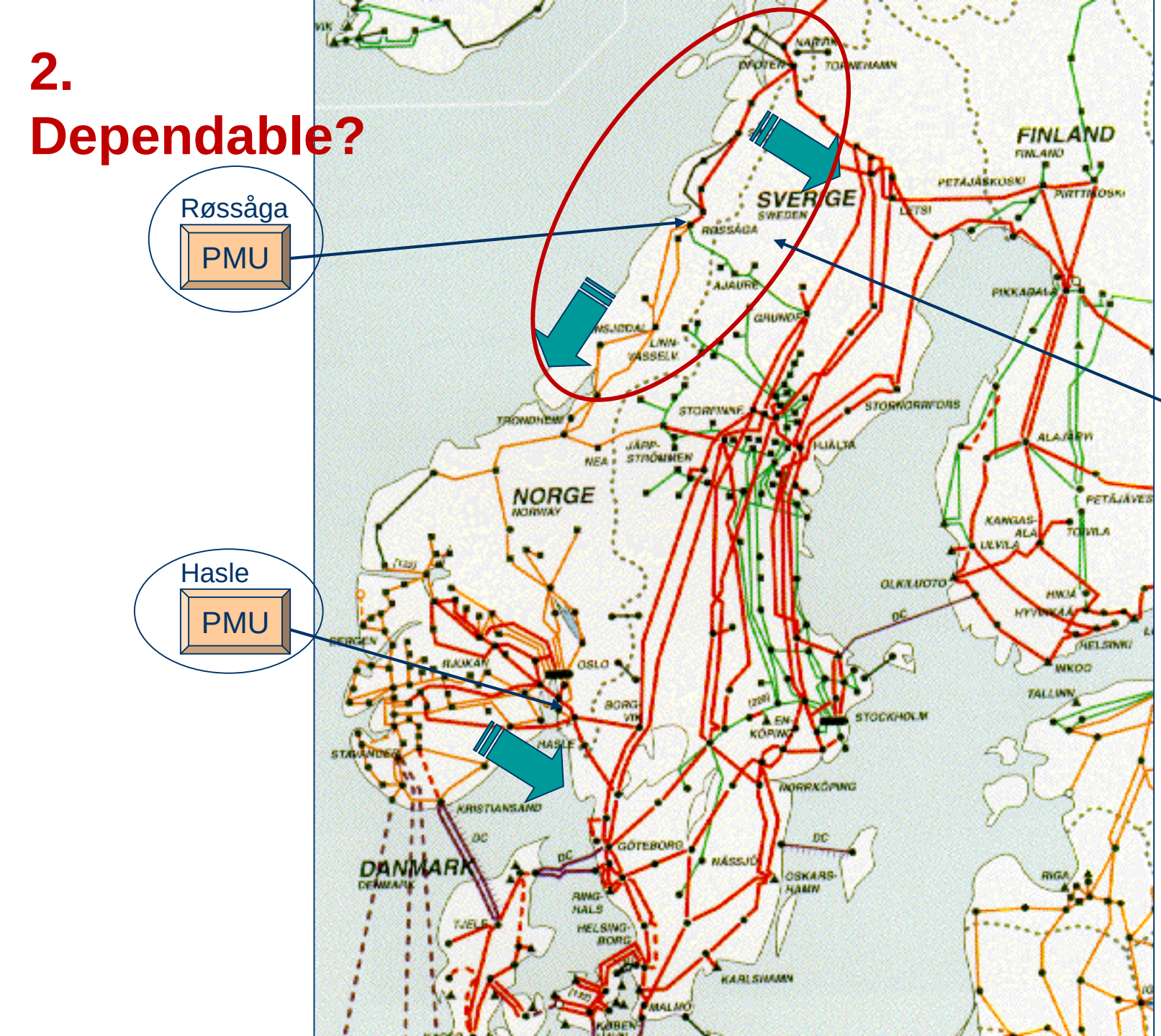
Short circuit fault sucessfully cleared

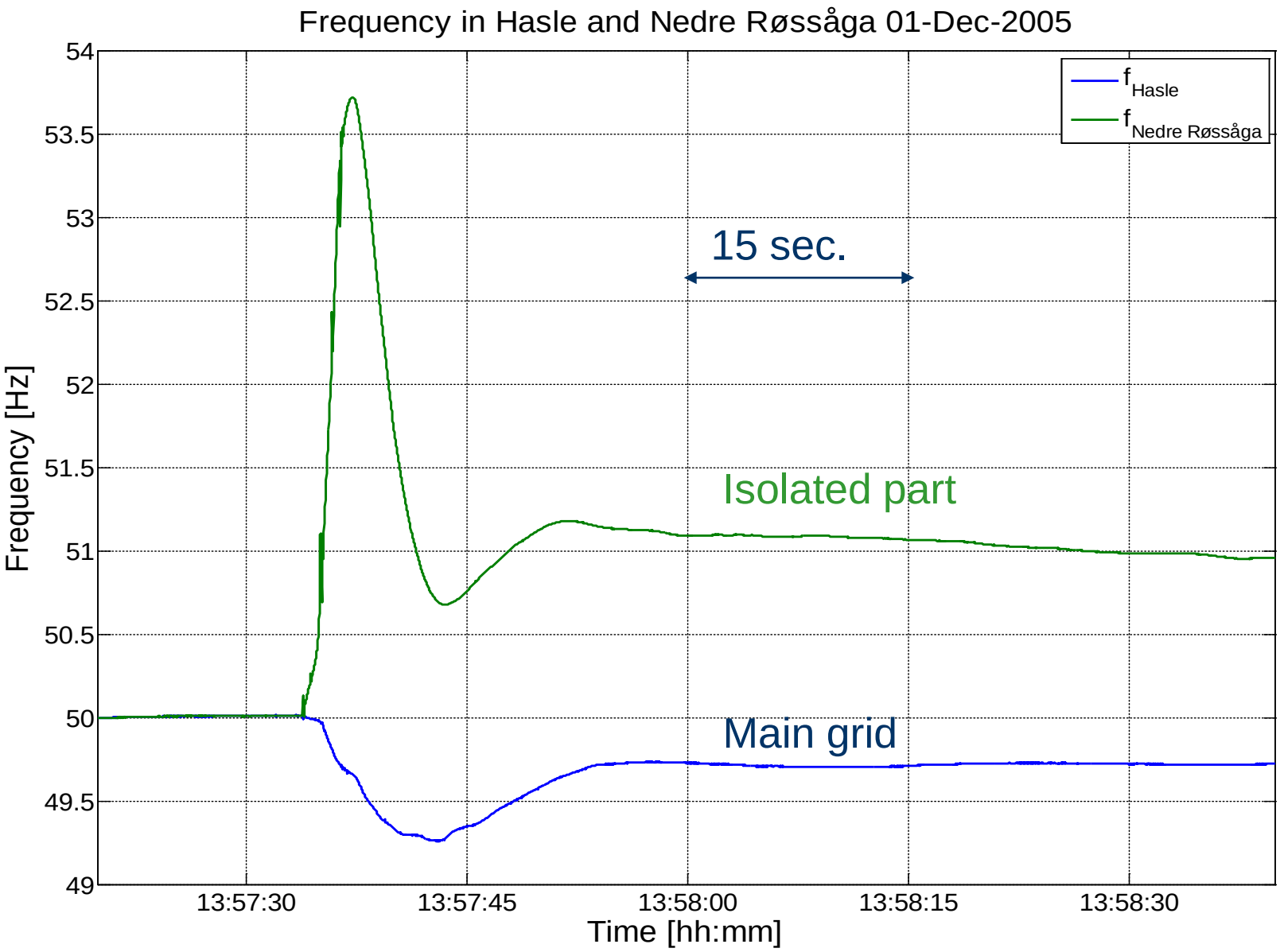
Reliable operation and design of System Protection Schemes (SPS)

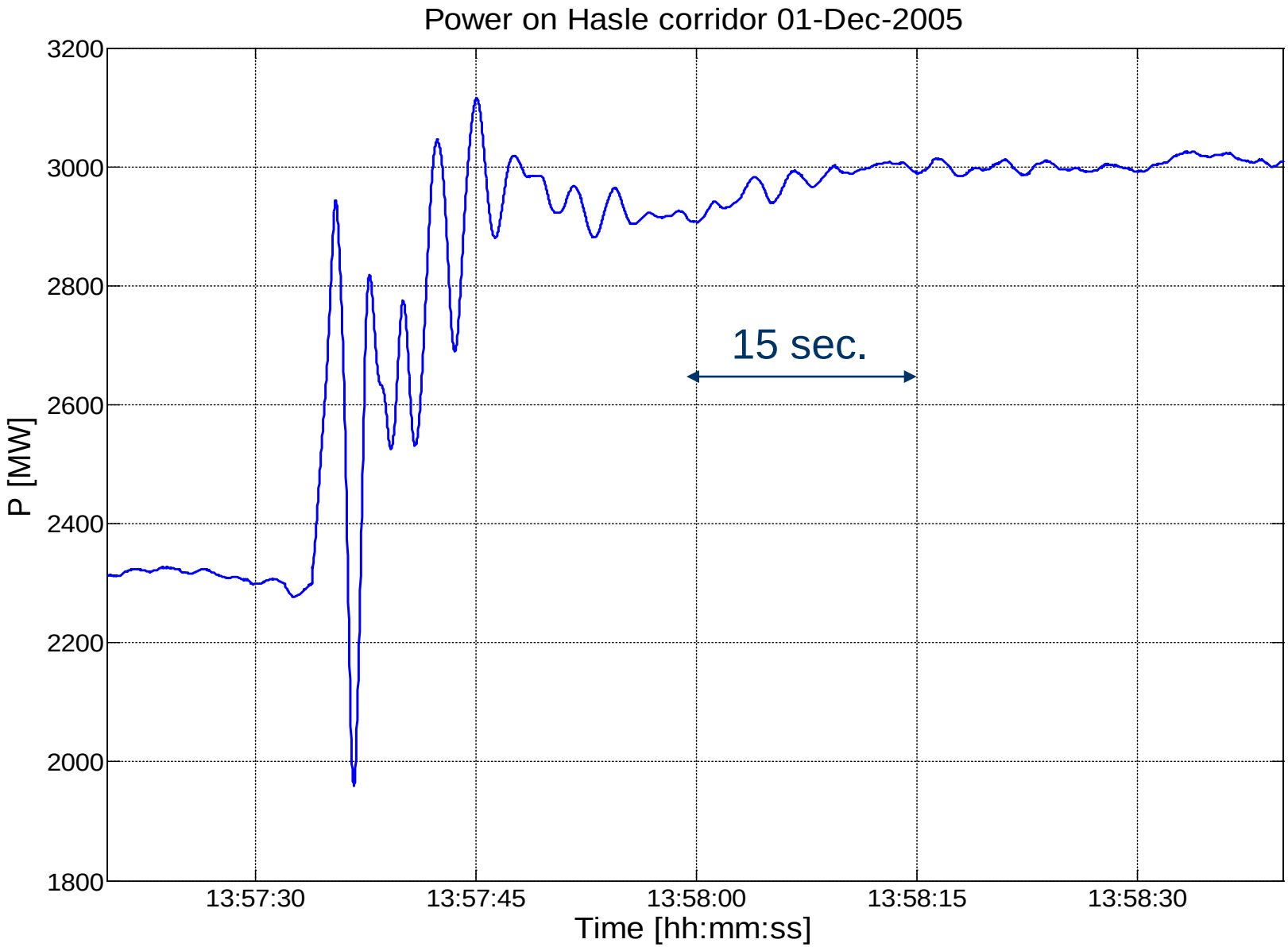


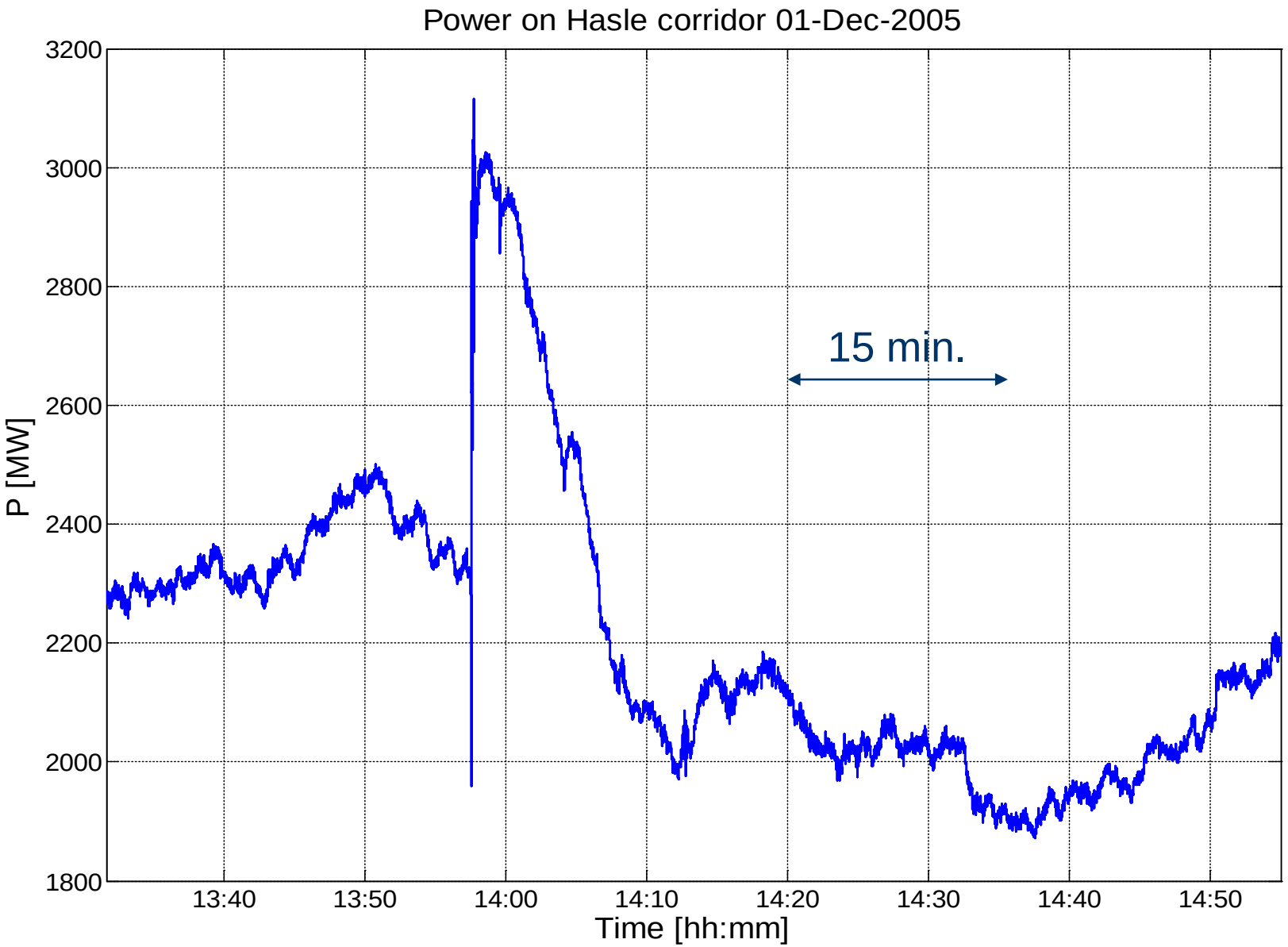
- Hasle SPS activation due to short-circuit in Sweden.
- Resulted in 1.1 GW of generator tripping.
- Unwanted and costly operation (?).
- How to improve activation of SPSs?

2.
Dependable?




Frequency in Hasle and Nedre Røssåga 01-Dec-2005
f Hasle
f Nedre Røssåga
15 sec.
Isolated part
Main grid
Frequency [Hz]
Time [hh:mm]
54
53.5
53
52.5
52
51.5
51
50.5
50
49.5
49
13:57:30
13:57:45
13:58:00
13:58:15
13:58:30


Power on Hasle corridor 01-Dec-2005
3200
3000
2800
2600
2400
2200
2000
1800
P [MW]
15 sec.
13:57:30
13:57:45
13:58:00
13:58:15
13:58:30
Time [hh:mm:ss]


Power on Hasle corridor 01-Dec-2005
3200
3000
2800
2600
2400
2200
2000
1800
P [MW]
15 min.
13:40
13:50
14:00
14:10
14:20
14:30
14:40
14:50
Time [hh:mm]

System Protection

Challenges:

- Better situational awareness
  - **More precise information about the state of operation is needed!**

- WAMS is key to design of secure and dependable SPs

System Protection

- ***Remedial action scheme based on synchrophasor measurements and system angle difference for Peru's 500 kV grid*** -- Yofre Jacome (Comité de Operación Económica del Sistema Interconectado Nacional, Peru), Eduardo Palma (SEL Latin America) & Luis Figueroa (Freeport McMoran, Inc.)

- ***Performance evaluation and review of System Protection Scheme design with the help of synchrophasor measurement in India*** -- Prithwish Mukhopadhyay, V. Pandey, Srinivas Chitturi, Chandan Kumar, Rajkumar, Sunil Patil & Malla Mahendranath (Power System Operation Corporation, India)

- ***NASPI System Protection Survey findings, NASPI Engineering Applications Task Team*** – Matthew Rhodes (Arizona Public Service)

System Protection

- ***Dynamic state estimation-based protection (a.k.a. setting-less protection)*** – Dr. Sakis Meliopoulos (Georgia Institute of Technology), Paul Myrda (EPRI), Bruce Fardanesh & George Stefopoulos (New York Power Authority)

- ***Real-time voltage stability monitoring: detection, extrapolation and prediction in Malaysia*** – Bozidar Avramovic, Rahul Anilkumar, Muhidin Lelic, Damir Novosel & Tony Jiang (Quanta Technology), Nik Sofizan B Nik Yusuf, Sheikh Kamar Sheikh Abdullah, Muhammad Tarmizi Azmi & Mohd Khairun Nizam Mohd Sarmin (Tenaga Nasional Berhad, Malaysia)

- ***Using wide area measurements to improve situational awareness and power system analytics in Finnish power system*** - Antti-Juhani Nikkilä, Mikko Kuivaniemi, Janne Seppänen (Fingrid Oyj)