19.9.2025 / Lasse Linnamaa

Säätöä verkossa – kantaverkkoyhtiön näkökulma

Is everything in control? Fingrid's view as a TSO of Finland

Automaatio vihreässä siirtymässä –webinaari:
Arvoketjun osien koordinointi ja sektori-integraatio
19.9.2025

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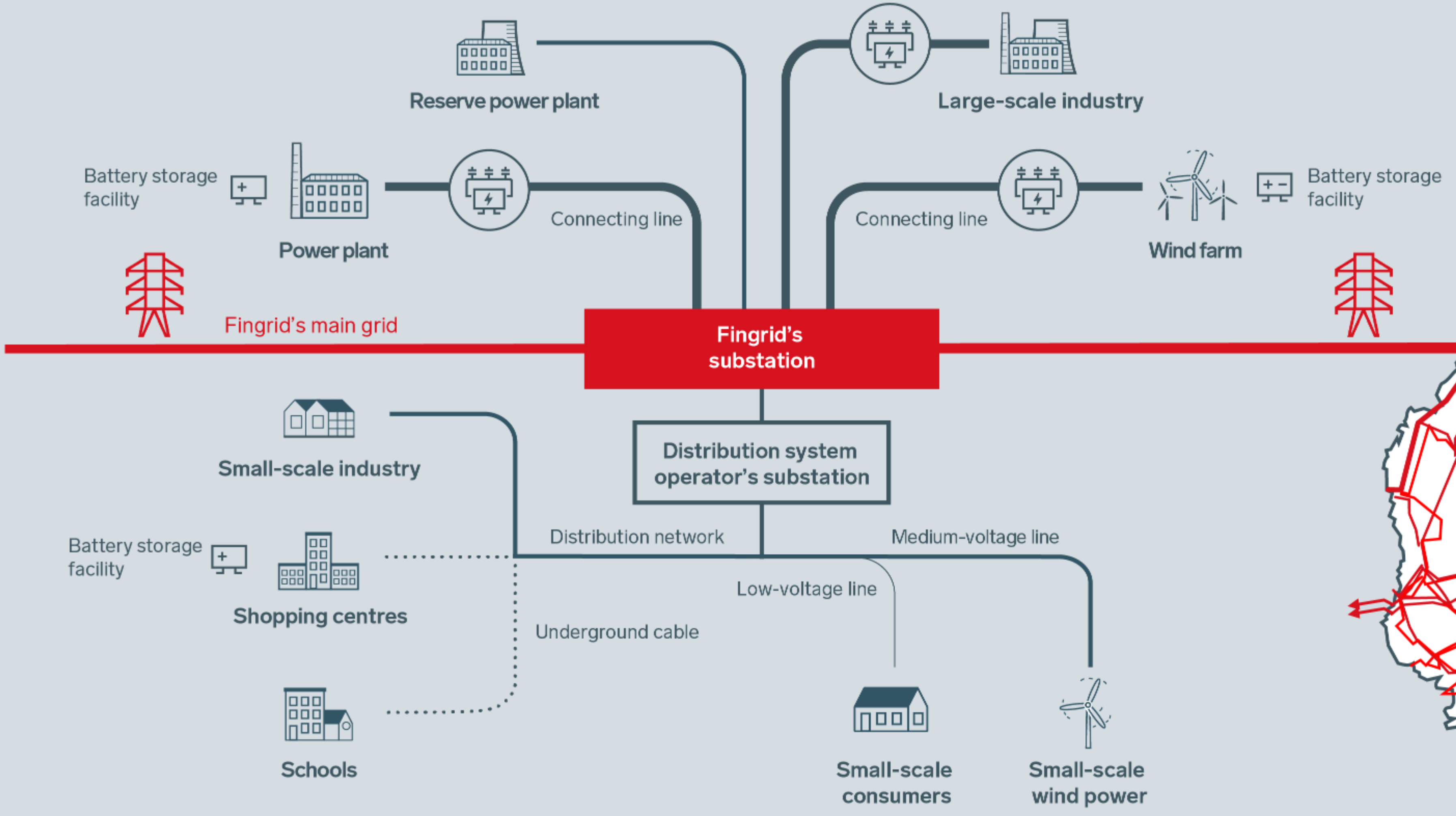
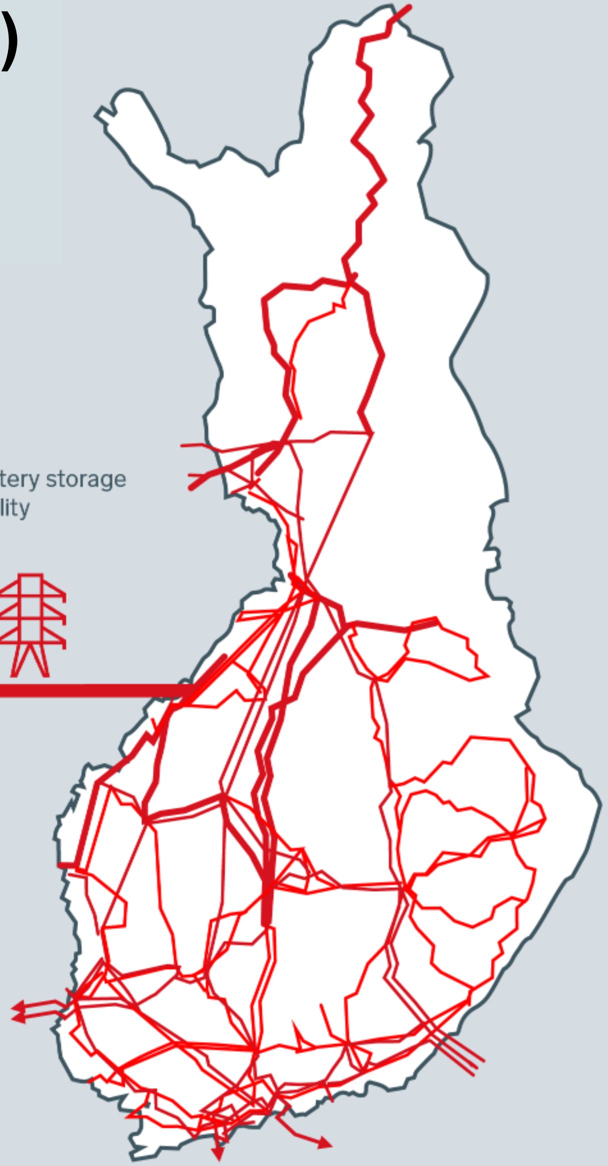
Fingrid is Finland’s transmission system operator (TSO)

Power system of Finland





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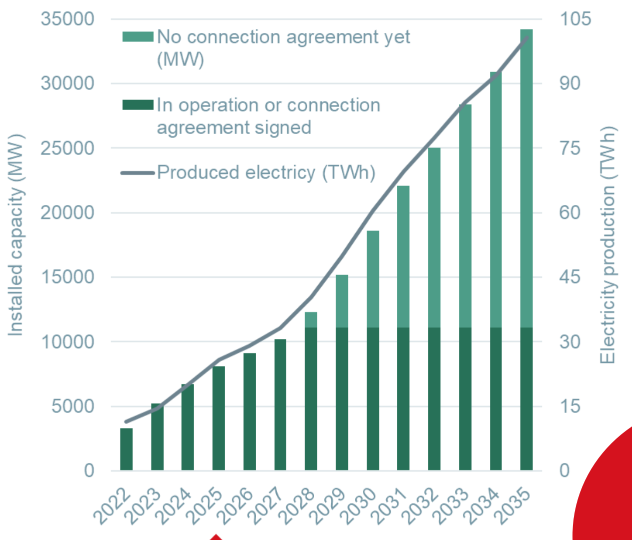
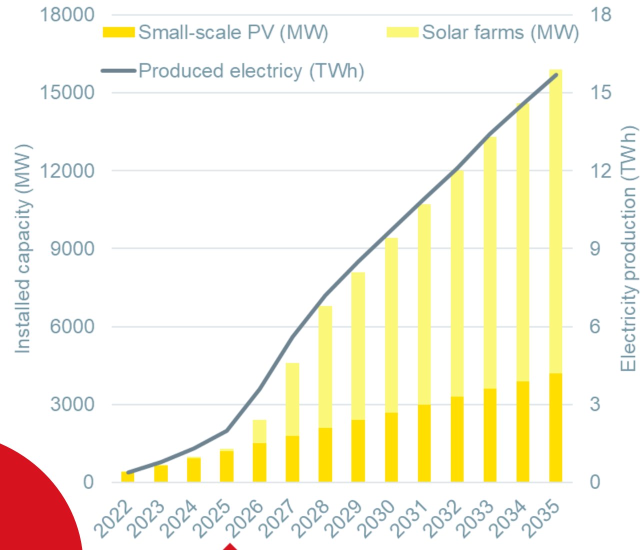
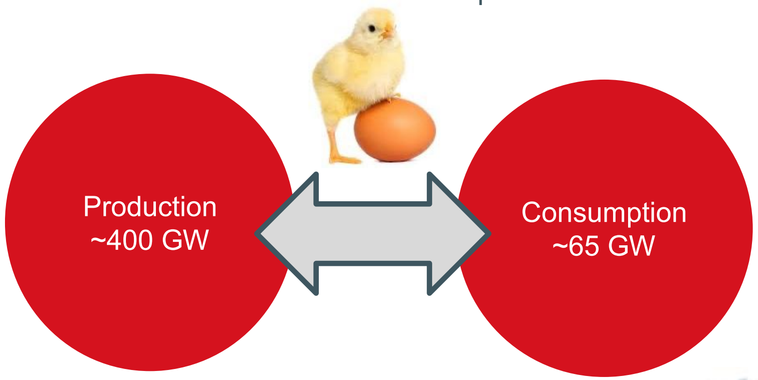
Wind and solar power vs. consumption

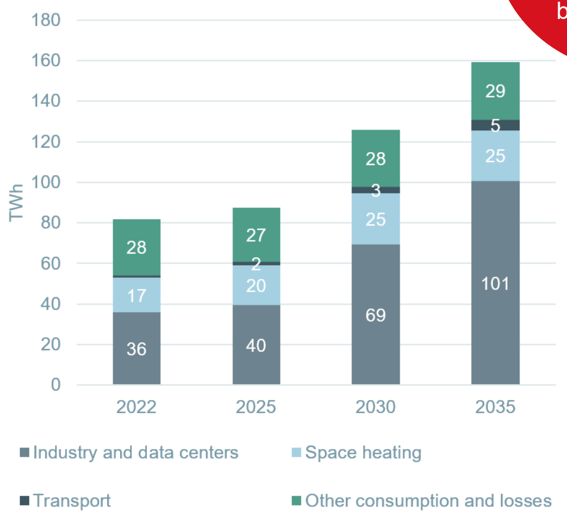


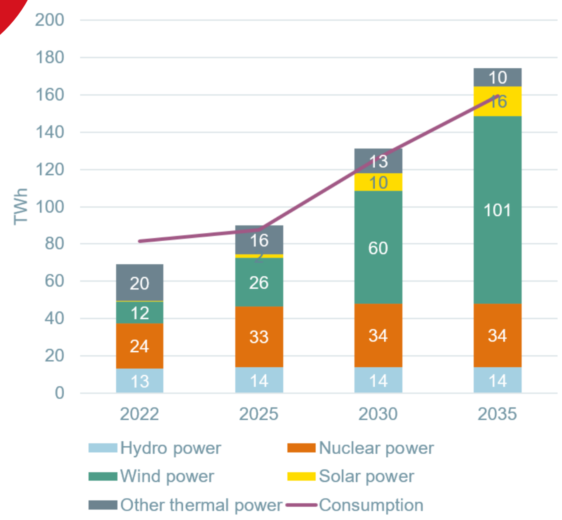


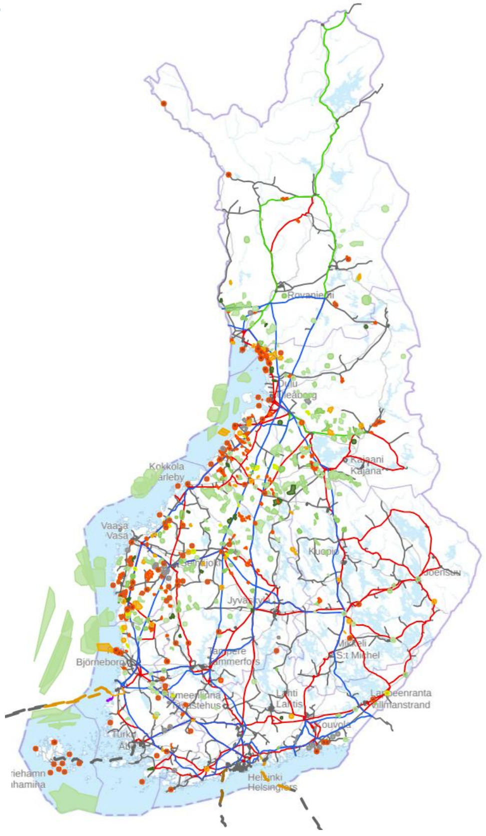
Amount of connection inquiries:

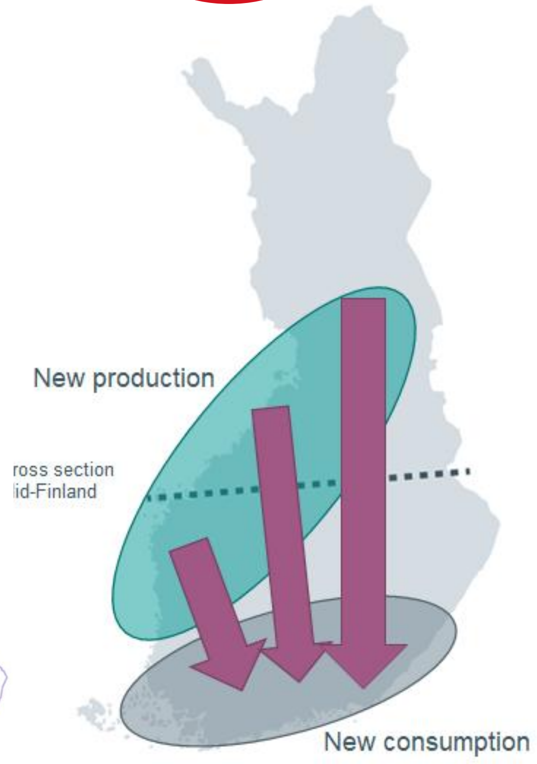


Energy storages: 27 GW requested, realistically several GW to be built in next 5 years









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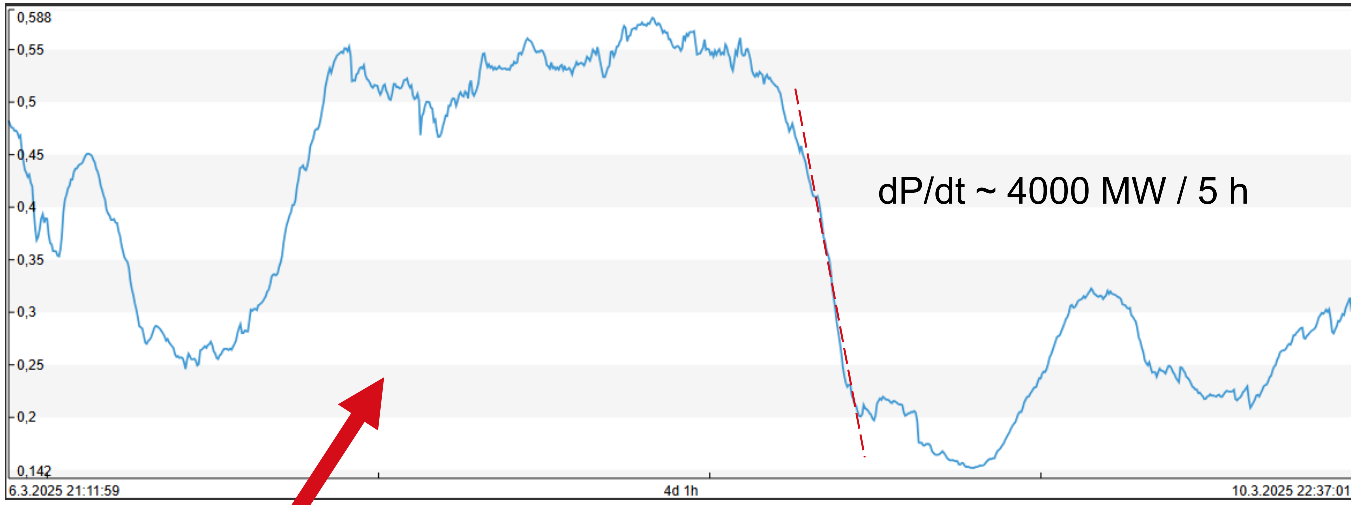
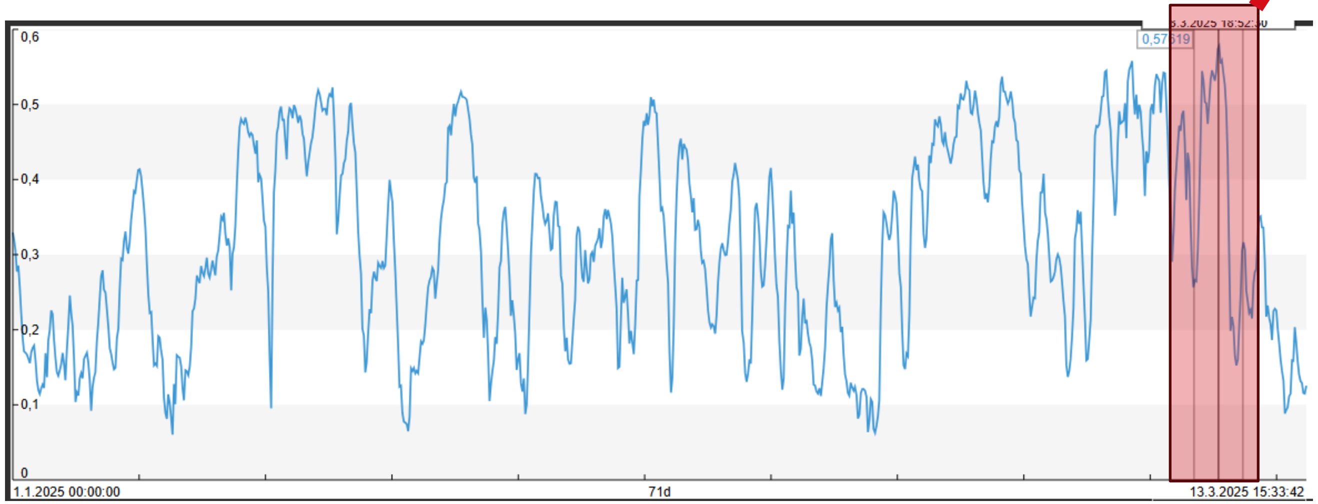
Amount of converter-connected production is increasing

9.3.2025 at 5am
Production in Finland 10GW out of which converters 58% (wind: 5GW)

5 hours later…

9.3.2025 at 10am
Production in Finland 7.5GW out of which converters 22% (wind: 0.8GW)





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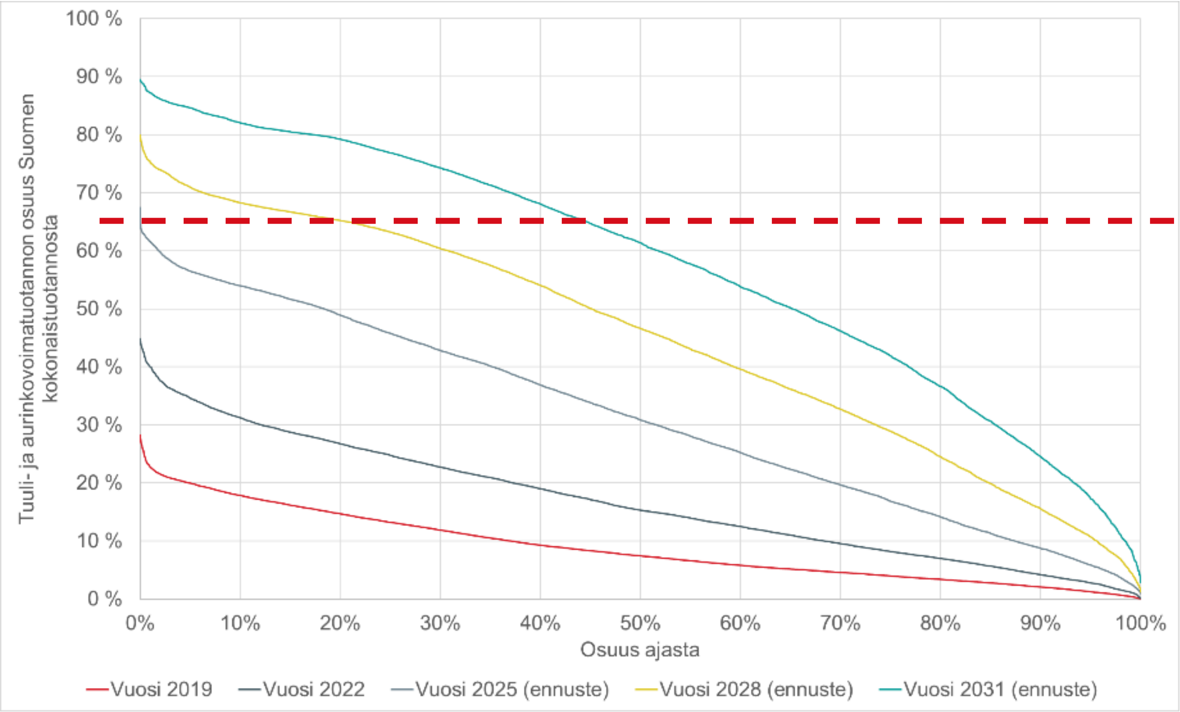
...and the growth continues



Time series presentation: proportional amount of wind and solar of Finland's total production vs. annual hours

No problem, right?

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Case: converter-driven instability

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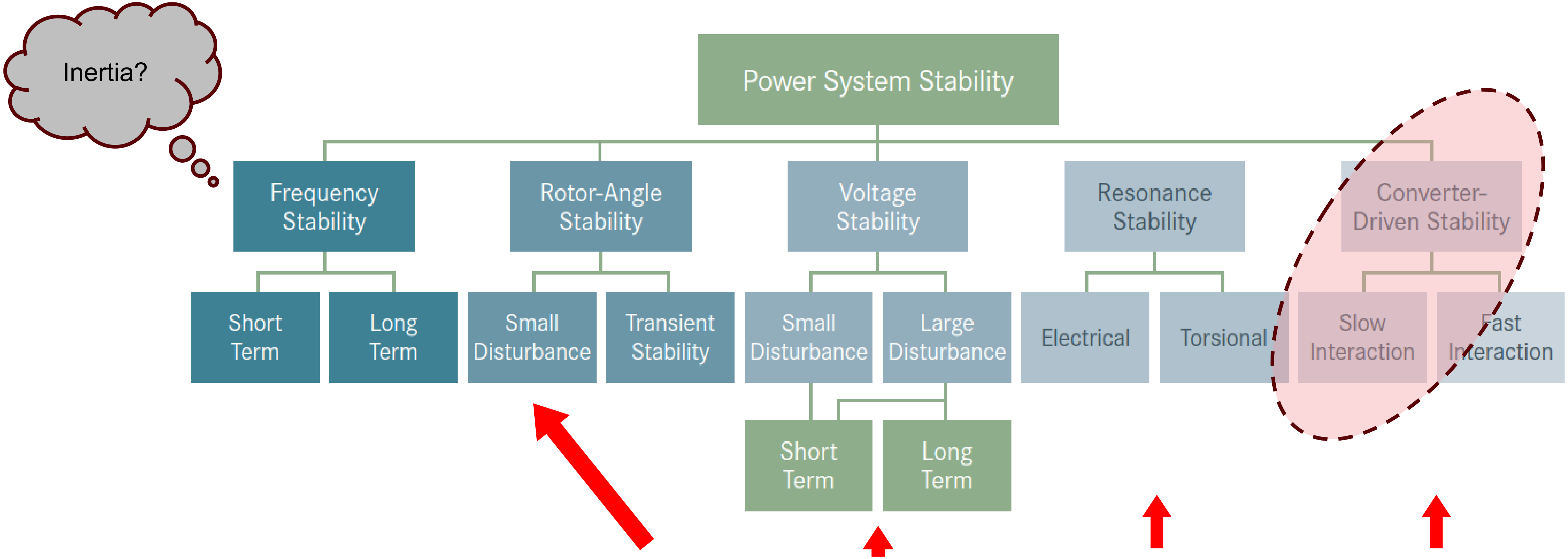
Power system stability phenomena



Main technical challenges within the Finnish part of the system

N. Hatziargyriou et al., "Definition and Classification of Power System Stability – Revisited & Extended", in IEEE Transactions on Power Systems, July 2021

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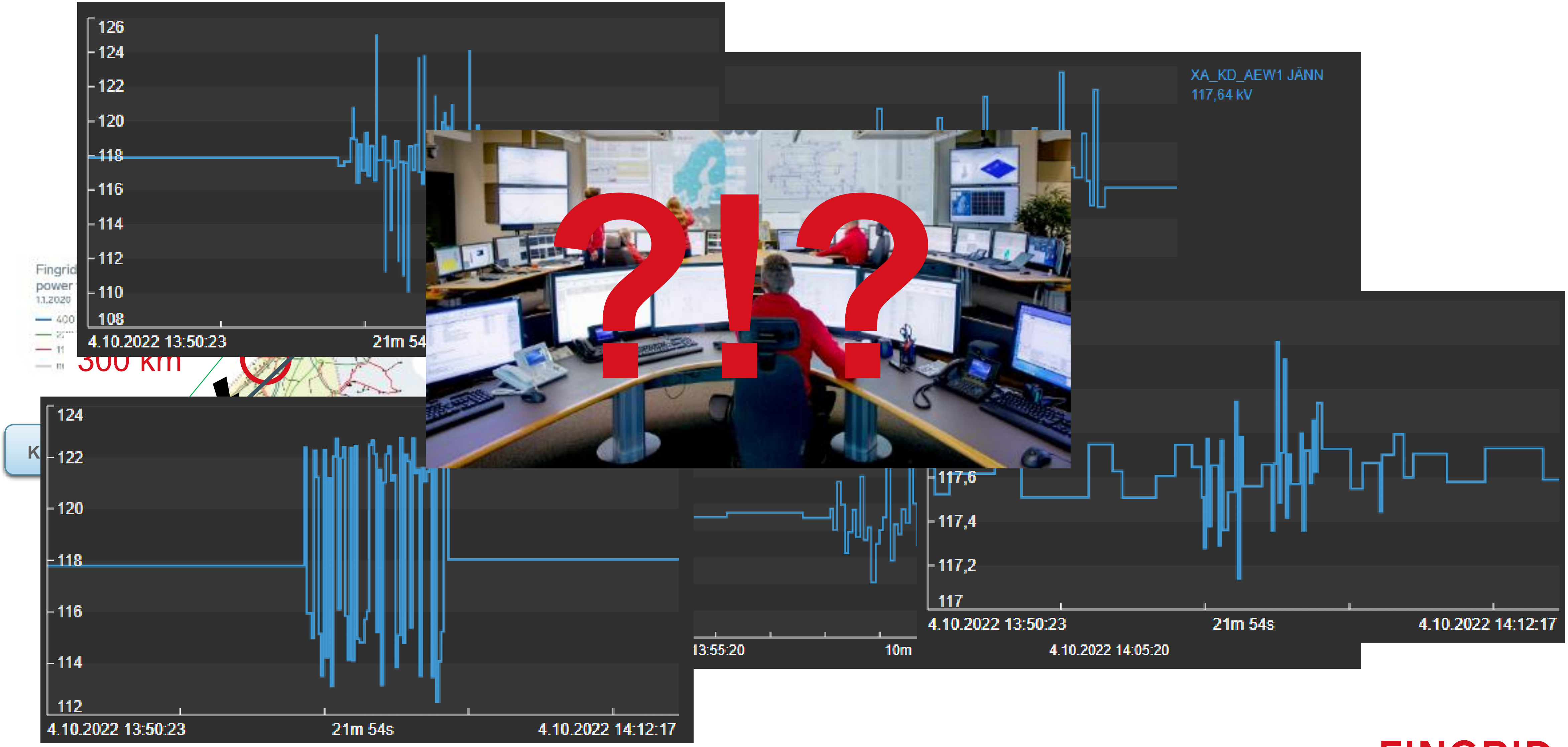
126
124
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110
108
4.10.2022 13:50:23
XA_KD_AEW1 JÄNN
117,64 kV
?!?
117,6
117,4
117,2
117
4.10.2022 13:50:23
21m 54s
4.10.2022 14:12:17
13:55:20
10m
4.10.2022 14:05:20
124
122
120
118
116
114
112
4.10.2022 13:50:23
21m 54s
4.10.2022 14:12:17

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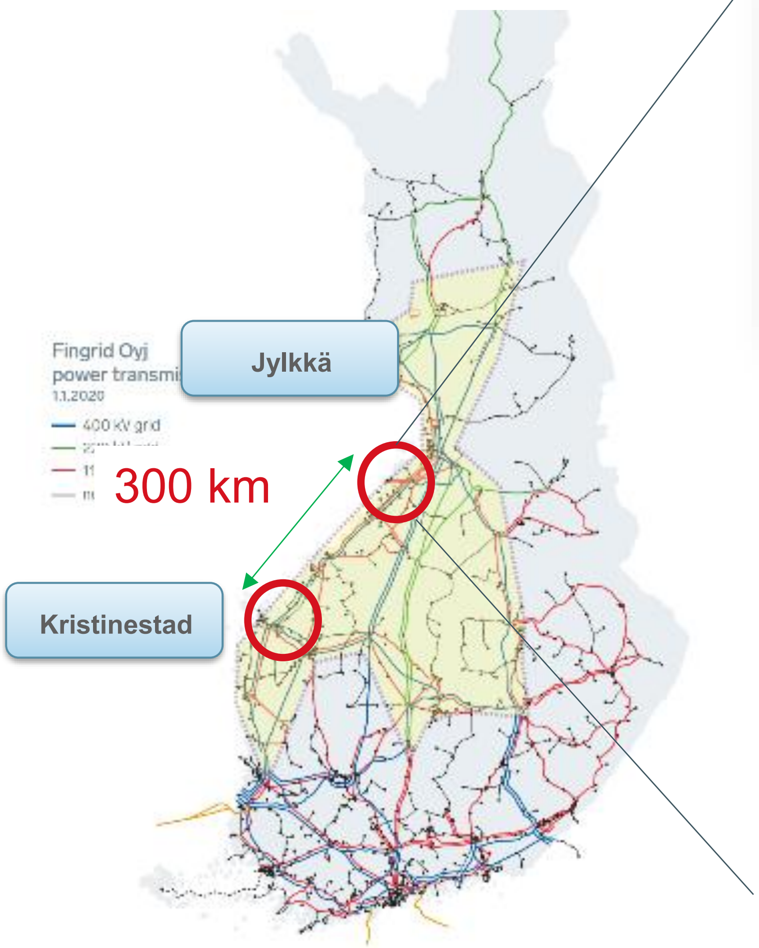
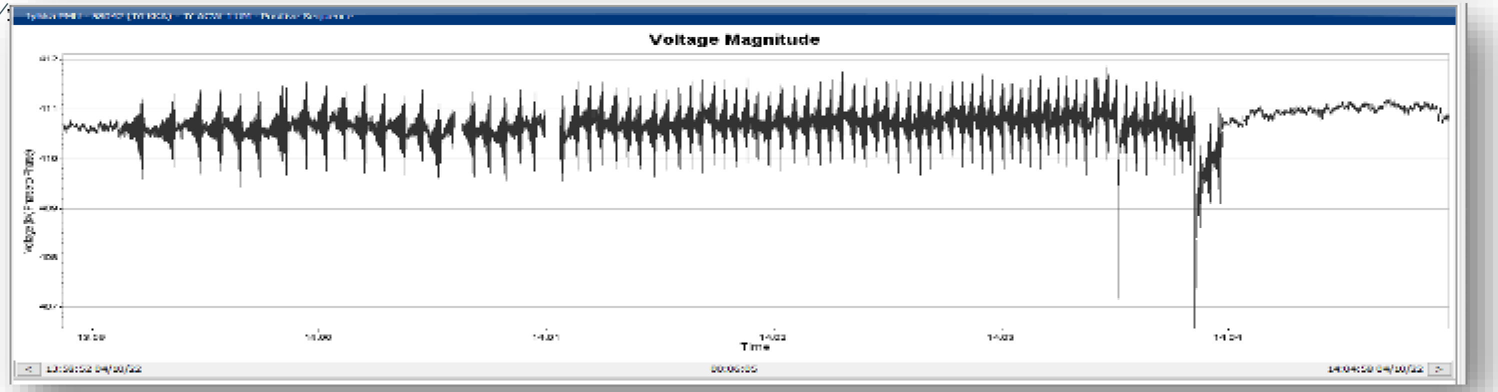
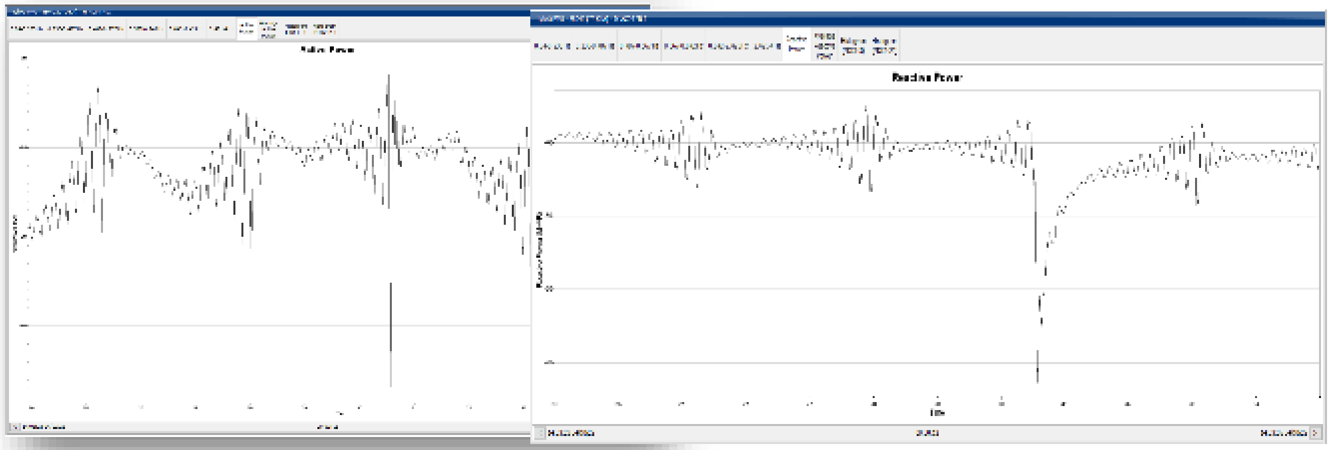
Case: converter-driven instability (regional controller instability)





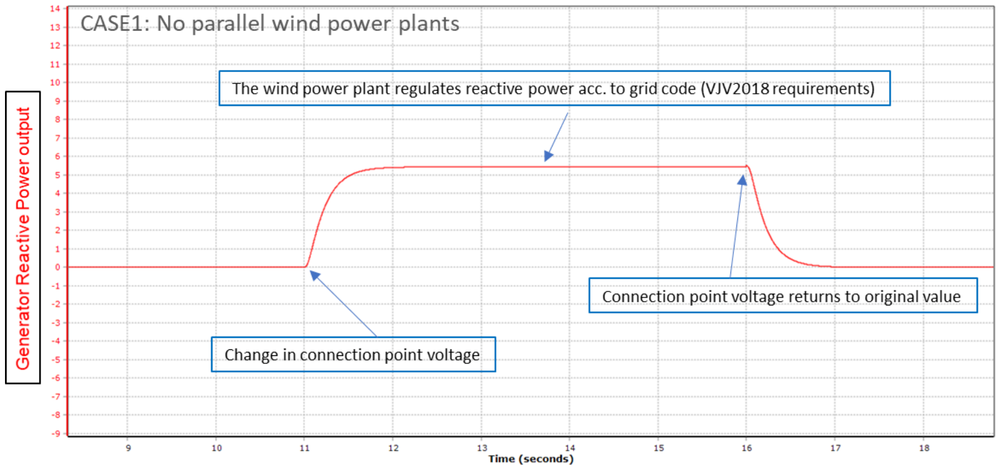
Voltage measurement

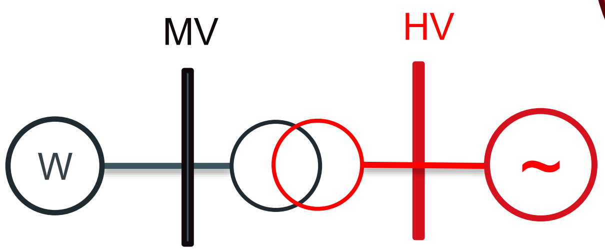


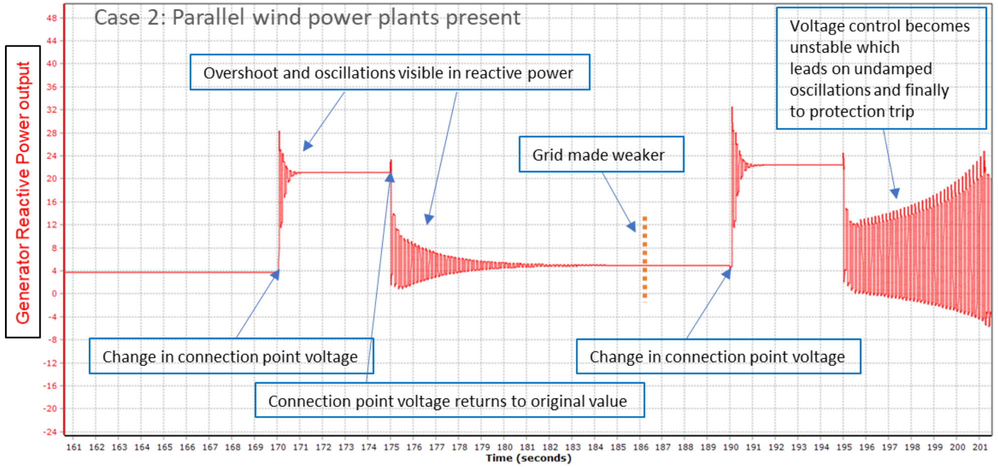
Active and reactive power measurements

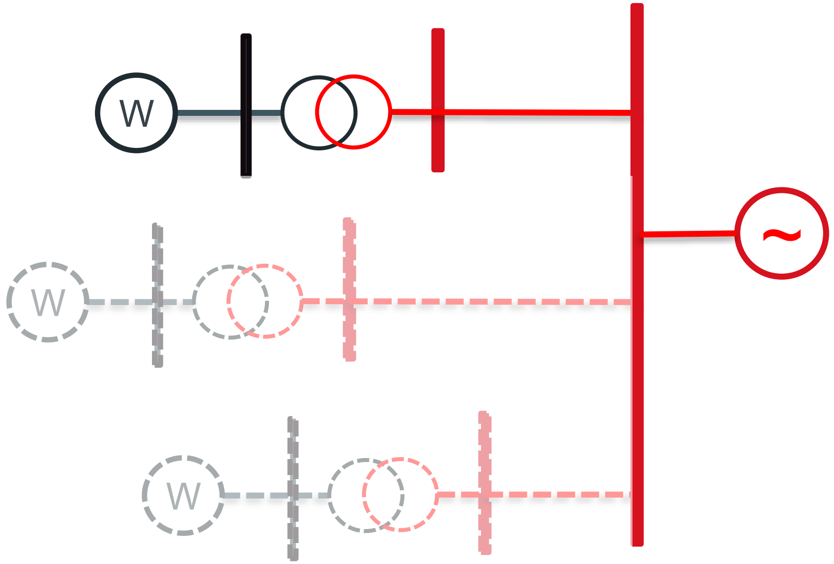
”More is less”

High active power level makes it worse!









For converter dominated area SCR (Short-circuit ratio) of a ”strong” grid appears as low from stability point of view!

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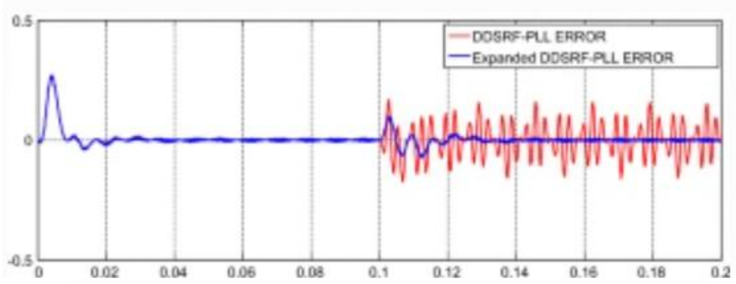
How to tackle the instability issues?

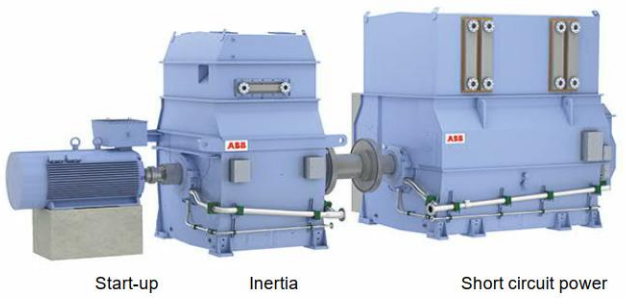
1) (re-)Tuning of controllers

- The ”easy” first step is to re-tune plant level voltage control (generally slower response enhances stability)
- More advanced way is to enhance lower level stability by modifying e.g. PLL operation → introducing ”weak grid solutions” to power plants



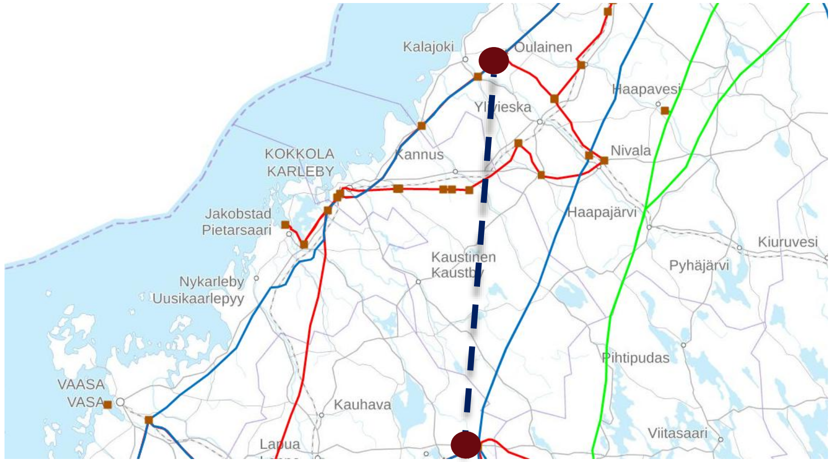
2) Installation of stabilizing devices

- Synchronous condensers and Grid Forming STATCOMs or Grid forming BESS which can stabilize grid-following converters
- Fingrid is already doing this: Syncon to Siikajoki in 2025, GFM STATCOMs to Kristiinankaupunki and Porvoo/Sipoo in 2027 and 2028



3) To build more power lines

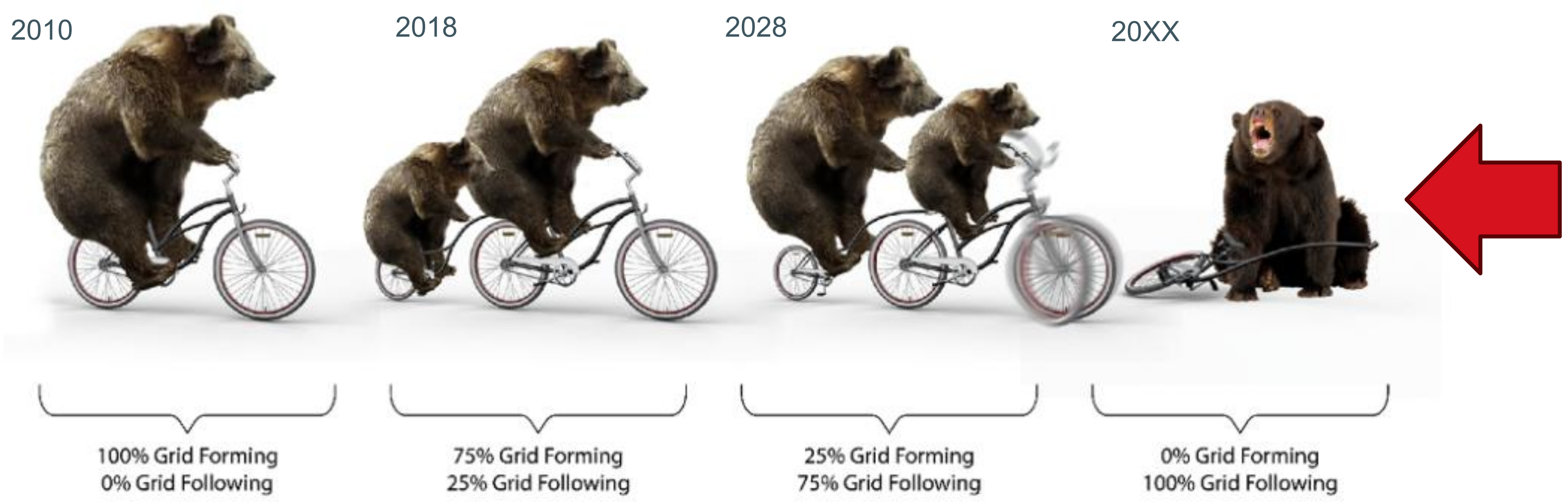
- New lines bring the connection point electrically closer to the existing synchronous machines
- This works only as long as the synchronous machines exist



Converter-driven stability of the power system - grid forming vs. grid following resources

At the moment, wind power and solar plants are Grid Following (GFL) – they are locked (via PLL) to system frequency and supply current (power) to grid. Control objective is to keep magnitude and phase of the current constant → acts as a current source.

Synchronous machines and grid forming inverters are Grid Forming as they can act as an independent voltage source. Control objective is to keep magnitude and phase of the voltage constant → acts as a voltage source.



Not OK!

Source:
Kenyon et al, 2020. Grid-Following Inverters and Synchronous Condensers: A Grid-Forming Pair, 2020 Clemson University Power Systems Conference (PSC)

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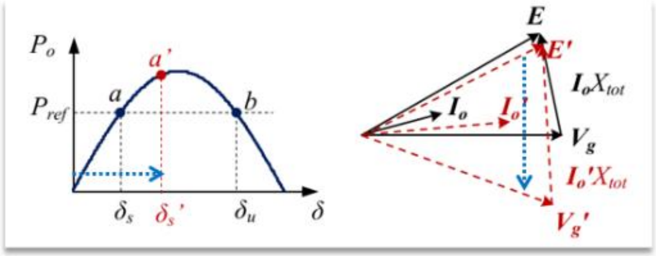
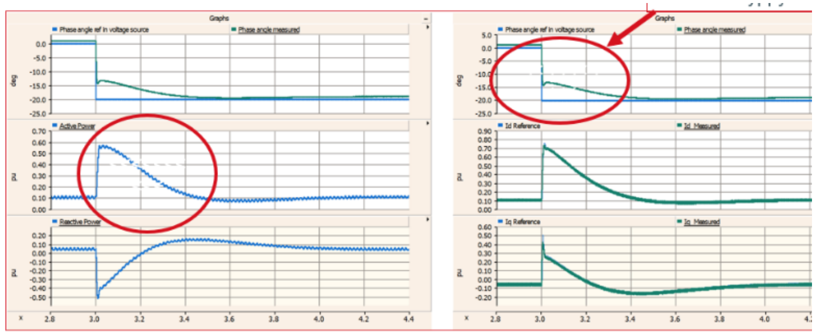
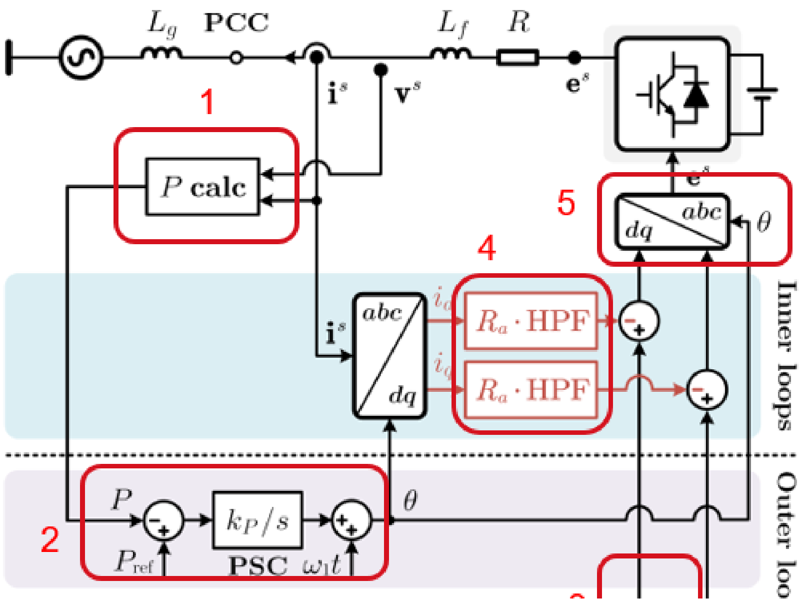
Future? Grid Forming inverters!





- Grid Forming (GFM) refers to control algorithms used in converters
- GFM technology is seen as an enabler of the converter-dominated power system, as when implemented correctly, it has the potential to ensure stable operation of converter-connected power plants even in a grid without synchronous machines.
- Fingrid has already set a requirement to implement GFM control for BESS (Battery energy storages) over 10 MW
- GFM is not (yet) available for wind and solar. Existing challenge is the inability to provide needed active power (inertial) response. To build more GFL wind power plants, one option is to equip new wind farms with GFM STATCOMs or GFM BESSs.
- GFM performs well only if it has been tuned properly!



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Case: Kulutuskohteiden häiriösietoisuus, säädettävyys ja vuorovaikutusilmiöt

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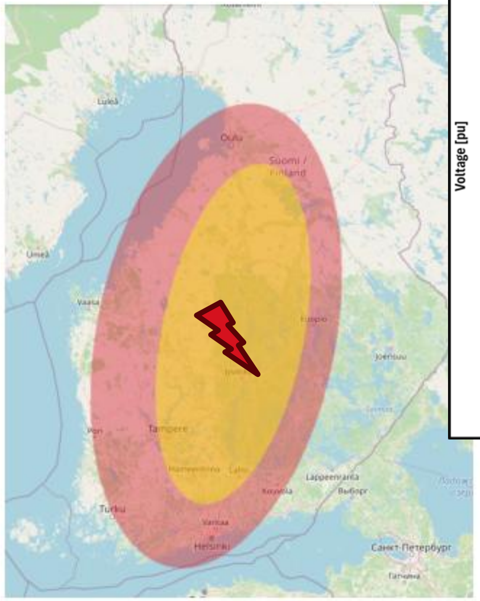
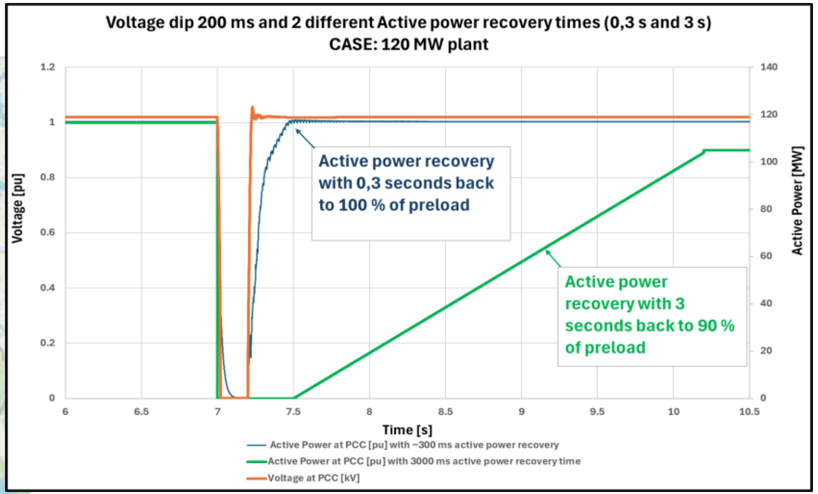
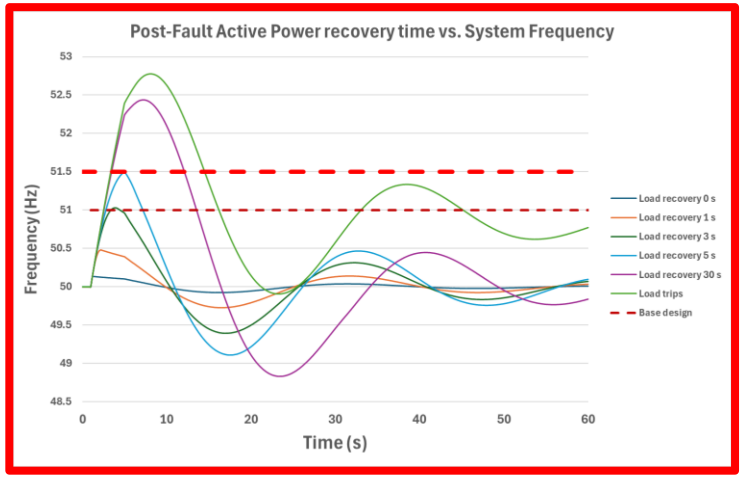
Suurien sähkön kulutuskohteiden toiminta häiriöissä

- Fingrid päivittää kulutuskohteille asettavat järjestelmätekniset vaatimuksensa vuonna 2026
  - Esim. datakeskukset, sähkökattilat, elektrolyyserit, prosessiteollisuus
- Taustaselvitysten mukaan suurten kuormakohteiden samanaikainen irtoaminen verkon jännitekuopissa voi vaarantaa koko sähköjärjestelmän käyttövarmuuden
- Tärkeää:
  - Lähivikakestoisuus
  - Tehon palautuminen vian jälkeen
  - Joustokyky (ohjattavuus, tehonsäätökyky)





Suuret kulutuslaitokset ovat monimutkaisia säätöteknisiä kokonaisuuksia! Koordinoitu vaste?



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Vuorovaikutusilmiöt?

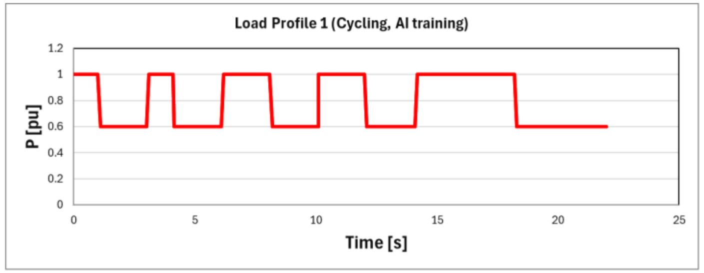
- Kuorman muutokset
  - Sähkön hinnan takia
  - Ympäristöolosuhteiden muuttuessa
  - Prosessista aiheutuva tehon syklinen vaihtelu
  - Tasainen kuorma?

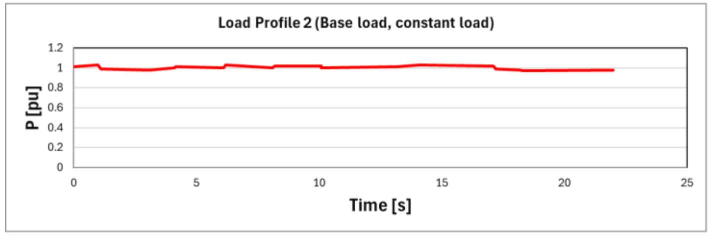
- Valtaosa tulevaisuuden kuormista on suuntaajakytkettyjä
  - Epälineaarisia
  - Ohjelmoitavaan tekniikkaan perustuvia
  - Verkkoa seuraavia suuntaajia

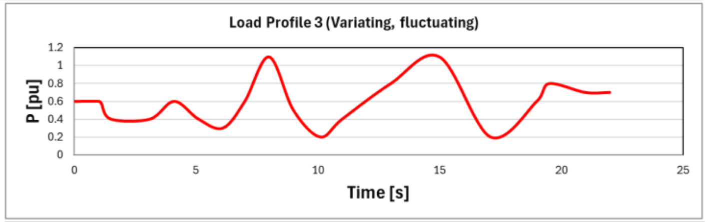
Osajärjestelmiä ohjataan itsenäisesti…

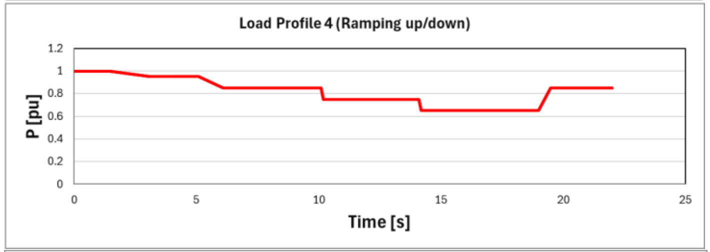
…mutta kuka vastaa kokonaisuuden koordinoinnista verkkovaatimusten näkökulmasta?

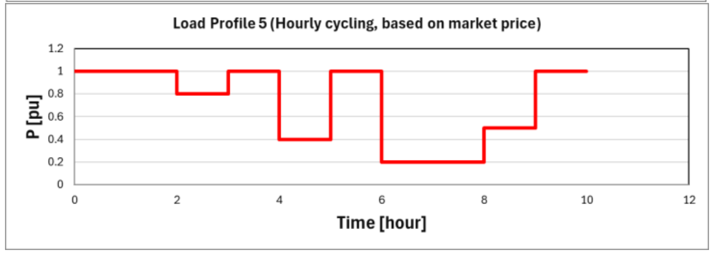
Uusia haasteita laitosautomaation suunnitteluun!











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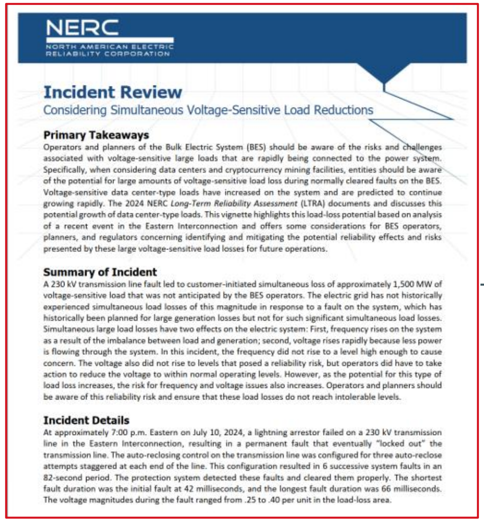
Varoittavia esimerkkejä: datakeskukset



NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Incident Review

Considering Simultaneous Voltage-Sensitive Load Reductions

Primary Takeaways

Operators and planners of the Bulk Electric System (BES) should be aware of the risks and challenges associated with voltage-sensitive large loads that are rapidly being connected to the power system. Specifically, when considering data centers and cryptocurrency mining facilities, entities should be aware of the potential for large amounts of voltage-sensitive load loss during normally cleared faults on the BES. Voltage-sensitive data center-type loads have increased on the system and are predicted to continue growing rapidly. The 2024 NERC *Long-Term Reliability Assessment* (LTRA) documents and discusses this potential growth of data center-type loads. This vignette highlights this load-loss potential based on analysis of a recent event in the Eastern Interconnection and offers some considerations for BES operators, planners, and regulators concerning identifying and mitigating the potential reliability effects and risks presented by these large voltage-sensitive load losses for future operations.

Summary of Incident

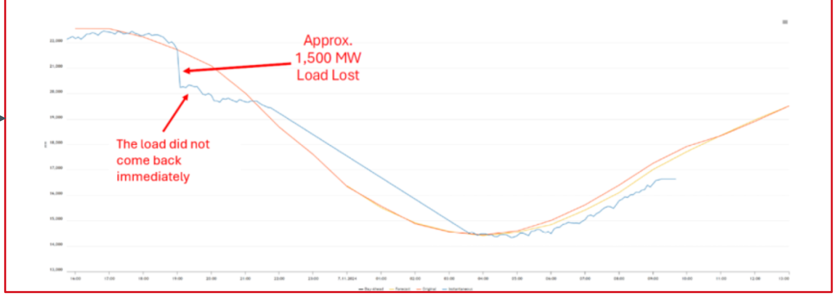
A 230 kV transmission line fault led to customer-initiated simultaneous loss of approximately 1,500 MW of voltage-sensitive load that was not anticipated by the BES operators. The electric grid has not historically experienced simultaneous load losses of this magnitude in response to a fault on the system, which has historically been planned for large generation losses but not for such significant simultaneous load losses. Simultaneous large load losses have two effects on the electric system: First, frequency rises on the system as a result of the imbalance between load and generation; second, voltage rises rapidly because less power is flowing through the system. In this incident, the frequency did not rise to a level high enough to cause concern. The voltage also did not rise to levels that posed a reliability risk, but operators did have to take action to reduce the voltage to within normal operating levels. However, as the potential for this type of load loss increases, the risk for frequency and voltage issues also increases. Operators and planners should be aware of this reliability risk and ensure that these load losses do not reach intolerable levels.

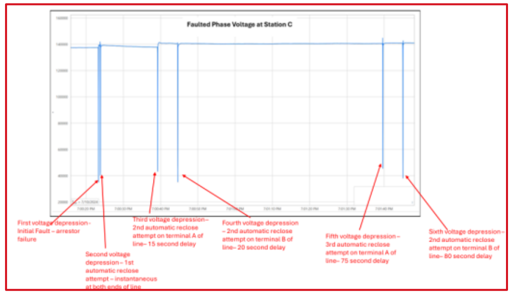
Incident Details

At approximately 7:00 p.m. Eastern on July 10, 2024, a lightning arrestor failed on a 230 kV transmission line in the Eastern Interconnection, resulting in a permanent fault that eventually "locked out" the transmission line. The auto-reclosing control on the transmission line was configured for three auto-reclose attempts staggered at each end of the line. This configuration resulted in 6 successive system faults in an 82-second period. The protection system detected these faults and cleared them properly. The shortest fault duration was the initial fault at 42 milliseconds, and the longest fault duration was 66 milliseconds. The voltage magnitudes during the fault ranged from .25 to .40 per unit in the load-loss area.

1500 MW lost due to UPS parametrization; approx. 60 datacenters

MW of load reduction was exclusively data center-type load. The area where the disturbance occurred has a high concentration of data center loads.

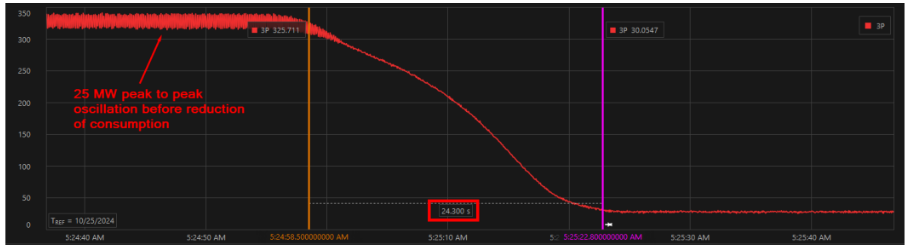




Discussions with the data center owners also identified another protection/control scheme that impacts the response of data center load to voltage disturbances on the grid. The scheme detects and counts voltage disturbances on the grid. If a certain number of voltage disturbances are seen within a certain time, the data center will transfer its load to the backup system, and it will remain there until it is manually reconnected to the grid. The typical number of voltage disturbances that trigger this scheme is three, and a typical time is one minute. As such, three voltage disturbances within one minute will result in data centers using this protection/control scheme transferring their load off the grid and staying off until they manually transfer back. This scheme can be deployed on both centralized and decentralized UPS designs. A load characteristic for this type of data center control scheme can be seen in Figure 10.

October 25 Event

- ERCOT observed the load dropped ~300 MW within a single telemetry scan on Oct. 25
- Load had increased consumption to ~330 MW over the previous week
- ERCOT sent RFI to interconnecting TO and requested PMU data from TO of POIB
- PMU data showed no fault preceding drop in consumption; load reduced ~300 MW over 24 second period
- Oscillation magnitude preceding reduction was ~25 MW peak to peak and ~7.5 Hz (later determined true oscillation mode was ~23 Hz from higher resolution data)
- Cause of reduction was reported to be an offsite telecommunication failure that triggered a load control issue



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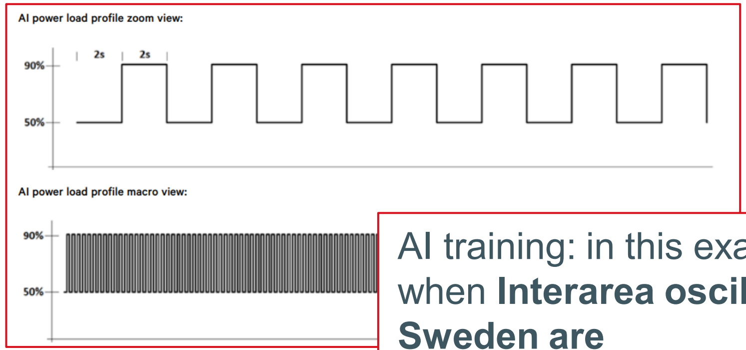

VERTIV: evaluating-performance-large-ups-ai-white-

AI training: in this example the load cycling is 0,25 Hz when **Interarea oscillations between Finland and Sweden are 0,30-0,40 Hz!**

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Kiitos!