9.11.2023 Minna Laasonen

Verification of RfG – experiences from production units in Finland

9.11.2023 Nordic Electric Power System Seminar
Chalmers University of Technology, Gothenburg

FINGRID

Content of the presentation

- Fingrid in short
- Changes of production capacity in Finland
- Verification of Grid Code Specification for Power Generating Facilities in Finland – VJV
- Example of verification: Forssa gas turbine
- Aspects to be considered when preparing for commissioning and VJV tests
- Developing requirements according to the observations

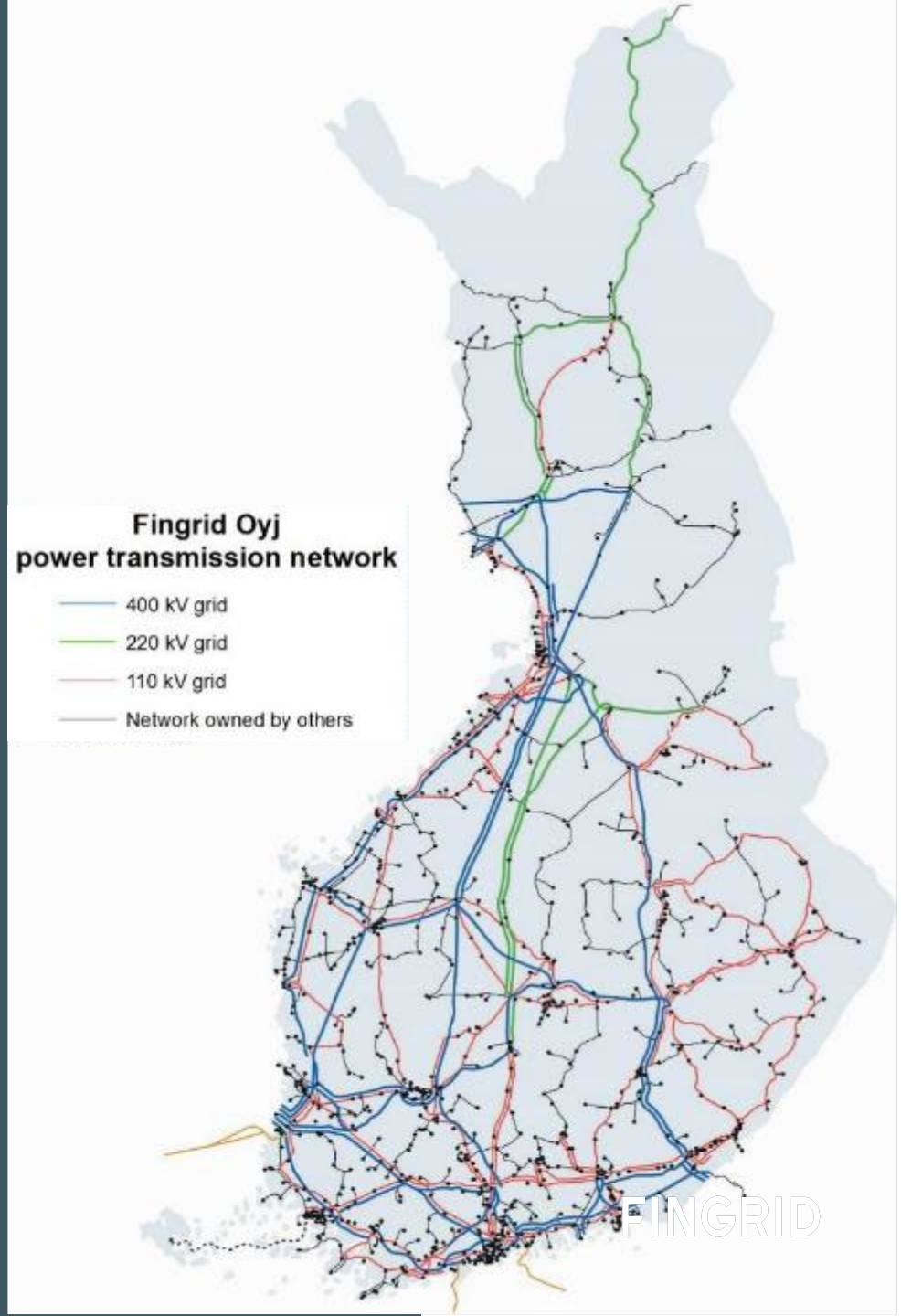
FINGRID

Fingrid in short

FINGRID

Fingrid is Finland's transmission system operator.

We secure cost effectively reliable electricity for our customers and society, and we shape the clean, market-oriented power system of the future.



Key figures

14,500
KILOMETRES OF TRANSMISSION LINES

TRANSMISSION RELIABILITY RATE OF THE MAIN GRID
99.99993 %

€ **3.2** BALANCE SHEET TOTAL BILLION EUROS

489 PERSONNEL

€ **1,815.2** NET SALES MILLION EUROS

€ **45.4** INCOME TAXES PAID IN 2022 MILLION EUROS

WORLD-CLASS IN CONDITION MANAGEMENT EFFECTIVENESS AND GRID RELIABILITY.

SOURCE: INTERNATIONAL TRANSMISSION OPERATIONS & MAINTENANCE STUDY

1 FINLAND'S MOST INSPIRING WORKPLACES

A RESPONSIBLE EMPLOYER

IN 2022, FINGRID'S NETWORK TRANSMITTED
70.1 TWh
ACCOUNTING FOR OF ELECTRICITY
78.4 %
OF TOTAL ELECTRICITY TRANSMISSIONS IN FINLAND

50 NET PROMOTER SCORE (NPS)

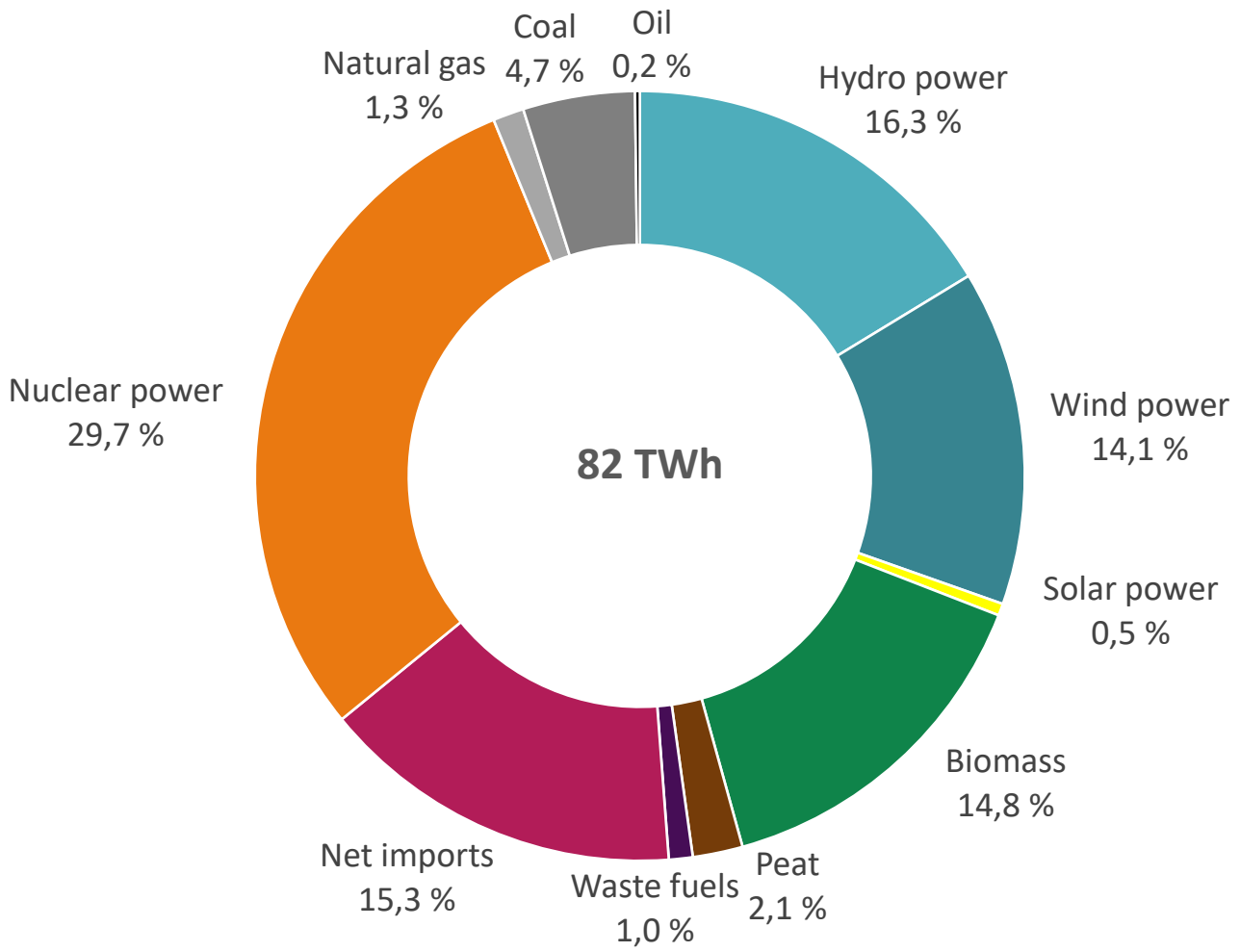
75 eNPS EMPLOYEE NET PROMOTER SCORE

Changes of production capacity in Finland

Source ”TVO”

FINGRID

Electricity consumed in Finland in 2022 by energy source



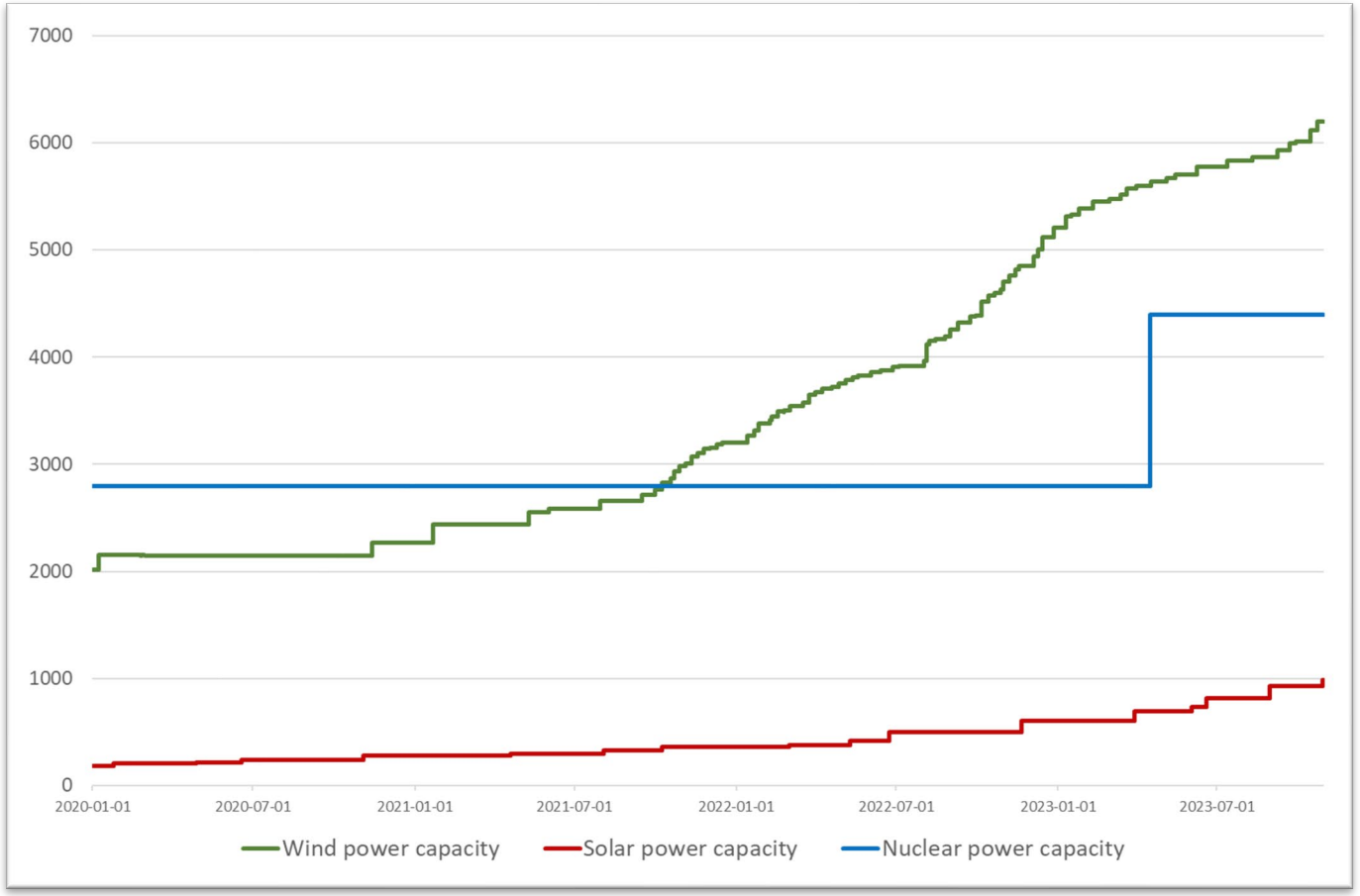
Source: Finnish Energy

FINGRID

Wind, solar and nuclear capacity has increased

- During couple of last year wind power capacity in Finland has tripled from 2000 MW to over 6000 MW.
- The amount of solar power has increased from 200 MW to 1000 MW
  - Small-scale solar
  - Large-scale solar will increase in coming years.
- Commissioning of Olkiluoto 3 has increased nuclear power capacity in Finland app. 1600 MW from 2800 MW to 4400 MW.

Wind, solar and nuclear power capacity in Finland 1.1.2020-31.10.2023.



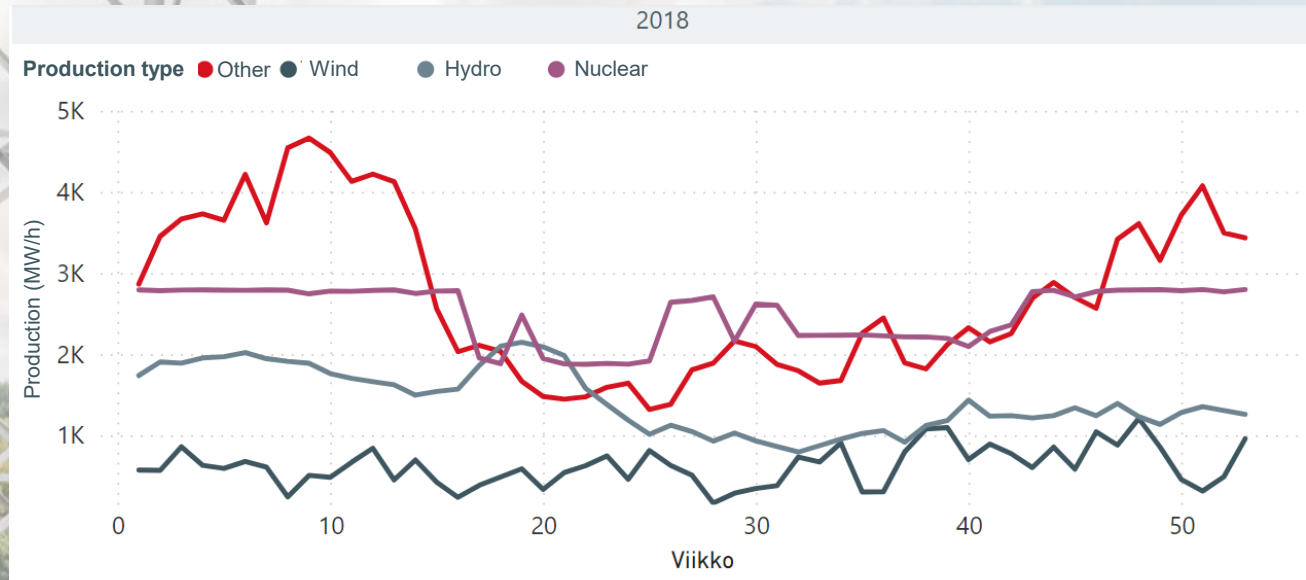
Energy revolution in Finland

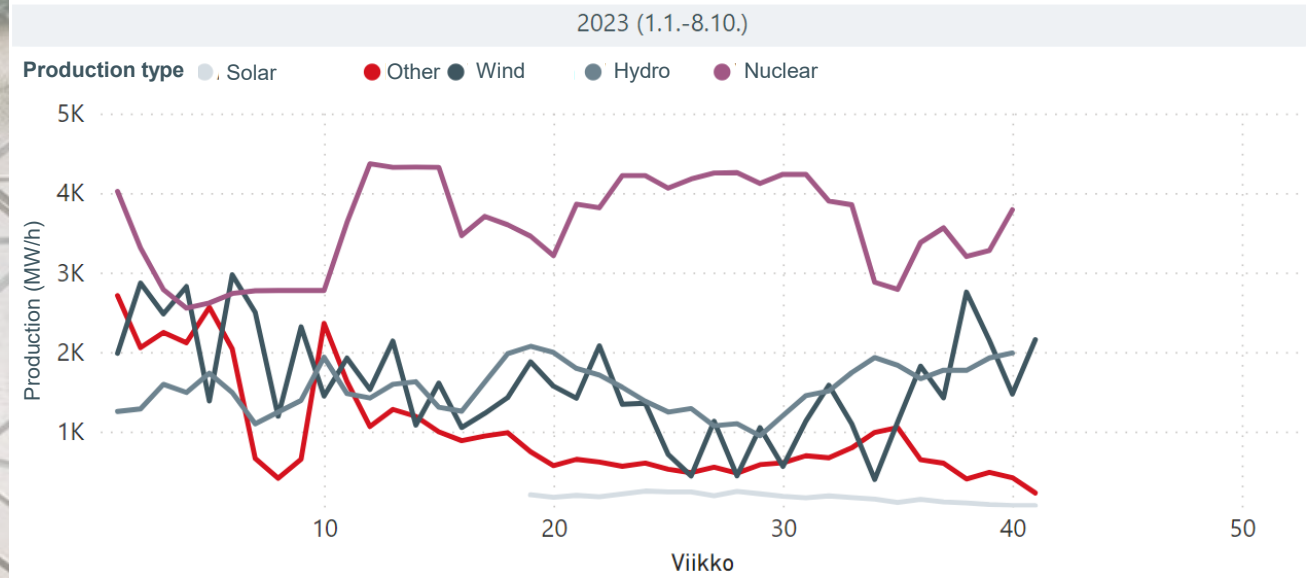
2018

- Low prices for fossil fuels and emission rights
- Finland is dependent on import
- First market-based wind power project in Finland

2023

- Onshore wind power in Finland is one of the most cost-efficient way to produce electricity in Europe
- Demand for clean energy is increasing
- Finland becomes net exporter for electricity
- Increase in weather dependent electricity production





Verification of Grid Code Specification for Power Generating Facilities in Finland - VJV

FINGRID

The purpose of the Grid Code Specification for Power Generating Facilities

- The specification defines the dynamic performance of the electric power system
- With the requirements the system security is ensured
  - The power generating facility withstands the voltage and frequency fluctuations that occur in the power system
  - The power generating facility supports the operation of the power system during disturbance situations, and operates reliably during and after such situations
  - The power generating facility does not cause any adverse impacts to the other installations connected to the power system
  - The relevant network operator and Fingrid obtains the data on the power generating facility, necessary in the planning of the power system and its operation and in the maintaining of system security

FINGRID

Currently VJV2018 is applied as Grid Code Specification for Power Generating Facilities

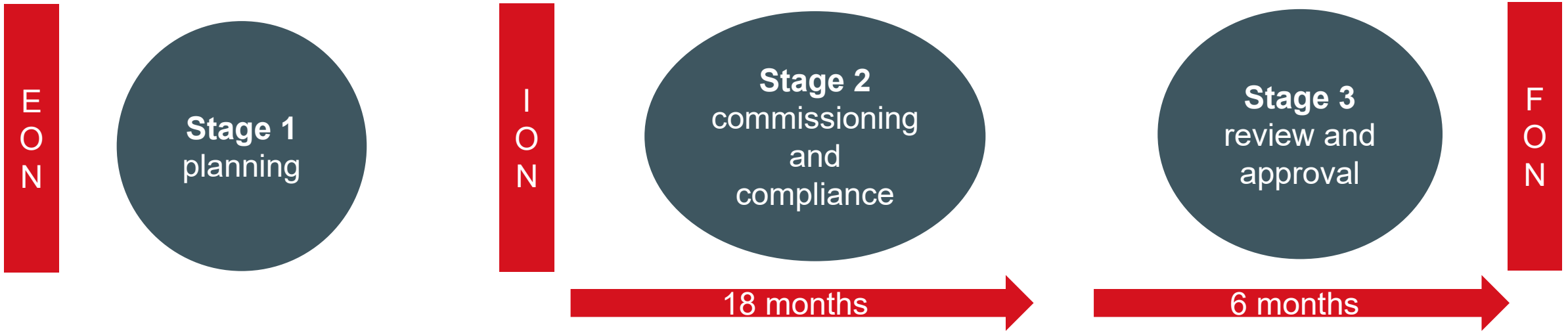
- New power generating facility owner must fulfil and maintain the specifications that were in force when the facility's connection agreement was concluded.
- The specifications shall apply also to existing facilities if their technical characteristics are changed.

Type category	Connection point's voltage level	Term/ condition	Power generating facility's rated capacity P_{max}
Type A	The connection point's voltage level is less than 110 kV	and	0.8 kW ≤ P_{max} < 1 MW
Type B	The connection point's voltage level is less than 110 kV	and	1 MW ≤ P_{max} < 10 MW
Type C	The connection point's voltage level is less than 110 kV	and	10 MW ≤ P_{max} < 30 MW
Type D	The connection point's voltage level is at least 110 kV	or	P_{max} ≥ 30 MW

VJV versions

- VJV 1996
- VJV 2000
- VJV 2007
- VJV 2013
- VJV 2018
- VJV 2024

Compliance monitoring process
type D power generating facilities



- Planning data
- Modelling data
- Required calculations
- Project-specific preliminary setpoints
- Delivery of real-time measurement data
- Statement of compliance

- Changes and updates to stage 1 data
- Planning and implementation of commissioning testing
- Reporting of test results
- Validation of modelling data
- Final setpoints of control devices and protection
- Statement of compliance

- Review of delivered data
- Approval of the process

EON – Energisation operational notification
ION – Interim operational notification
FON – Final operational notification

VJV2018 and commissioning tests

Type D

VJV2018 tests during commissioning for converter connected power park modules

- Operation of voltage control (voltage droop, Pf, reactive power control)
- Operation of frequency and active power regulation
- Reactive power capacity, both inductive and capacitive
  - P=10…20% / 60 min, P=30…50% / 30 min, P=>60% / 30 min
  - Performed inside the voltage limits defined by the operational situation
- Rapid power down regulation (100→20% / 5 s)
- Starting and stopping
- Fault-ride-through (FRT) capability
  - The need of FRT test is assessed case-by-case
- Additional damping control of electromechanical oscillations

VJV2018 tests during commissioning for synchronous power generating modules

- Frequency and active power regulation
- Voltage control tests
- Reactive power capacity test and restriction of active power
- Voltage control step response test at no load
- Transition to house load operation
- Fault-ride-through (FRT) capability
  - The need of FRT test is assessed case-by-case
- Power system stabiliser (PSS) tuning

Example of verification: Forssa gas turbine

FINGRID

Forssa power plant

The machinery consists of two gas turbines, each with its own generator and transformer

- Power 2 x 150 MW
- Start-up time < 15 min

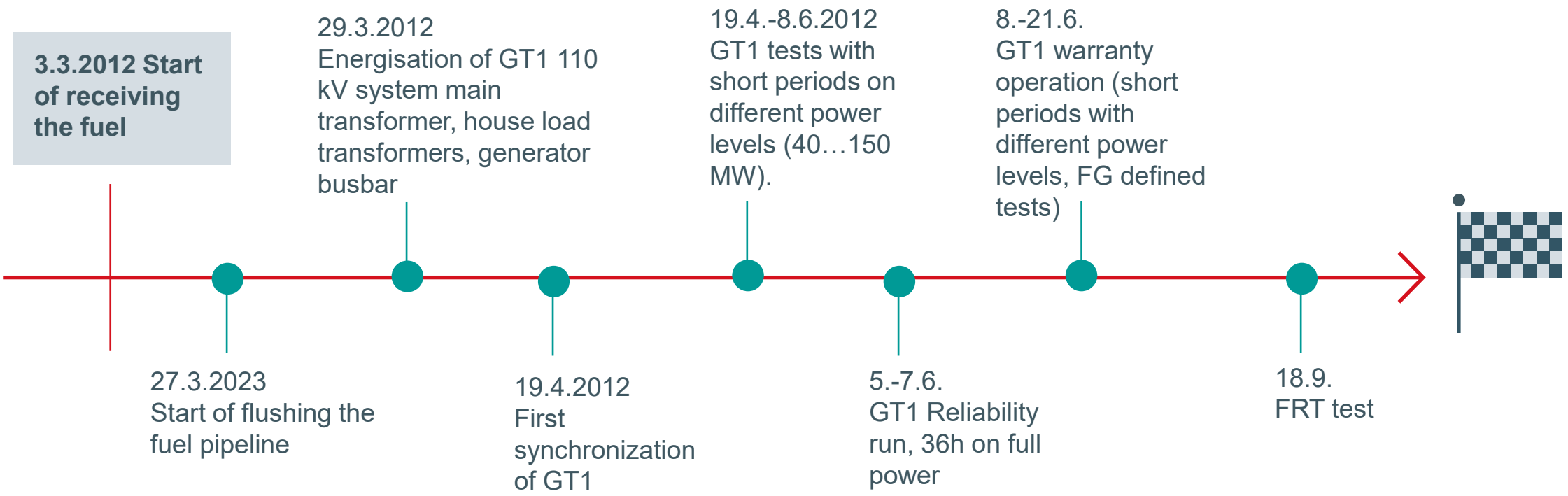
Generators

- U_N = 15,75 kV
- S_N = 175 MVA
- I_N = 6415 A
- pf = 0,85

Transformers

- U_N = 118/15,75 kV
- S_N = 175 MVA
- YNd11

Forssa power plant commissioning

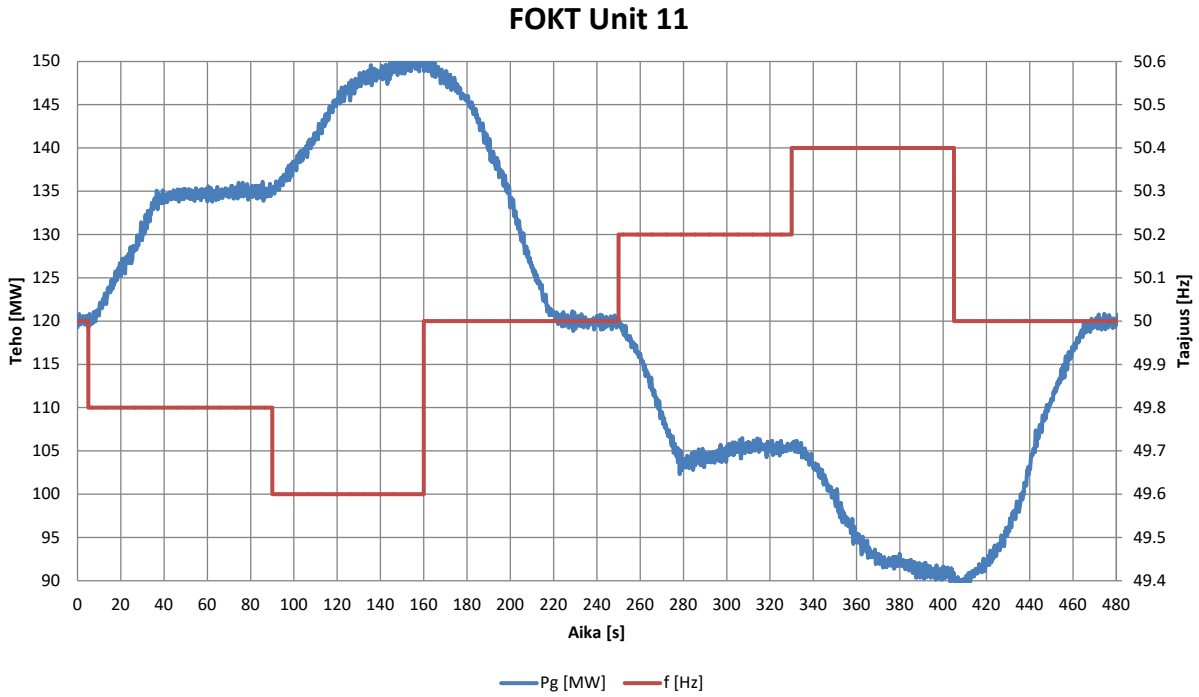


Similar tests for GT2: 18.6.-21.8.2012

Summary of Forssa VJV2007 tests

Verified properties

- Operation on minimum power
- Reactive power capacity on maximum and minimum power
- Operation of reactive power and voltage control
- Operation of real power and frequency control
- Transition to house load operation
- Operation during voltage disturbance (Fault Ride Through test)



dead band: ± 10 mHz
droop: 4 %
power limit: 30 MW/min

FINGRID

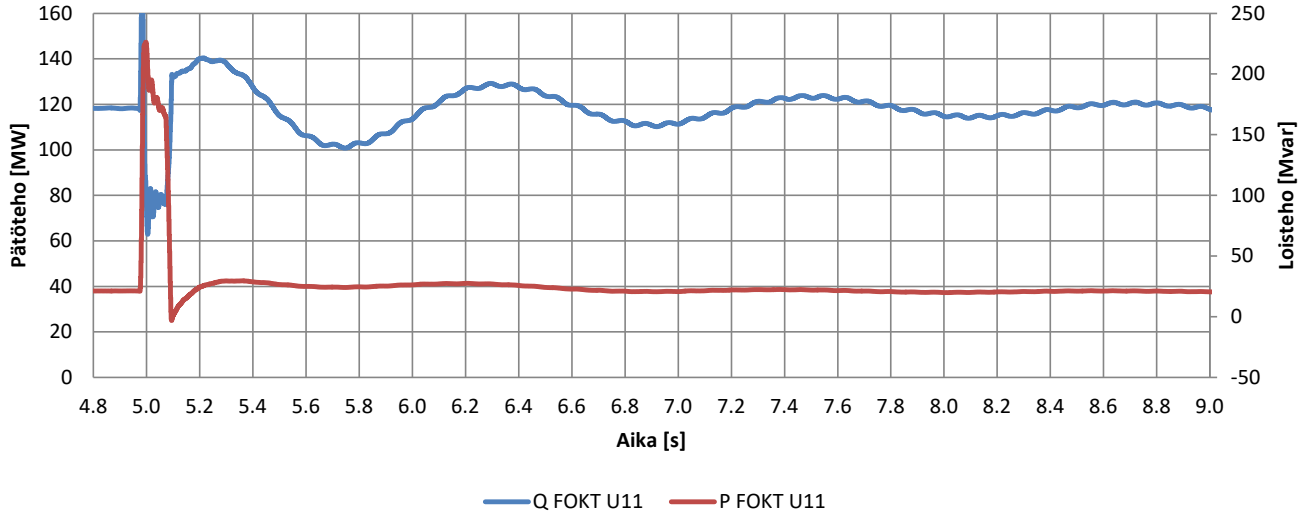
Planning of the operation during commissioning

- During commissioning tests Forssa power plant produced power to grid. One issue to be solved was how to handle this power.
- Solution: power was primarily used to the losses created in Fingrid transmission grid. Possible extra power could have been sold in intraday market
- Market information!
- Planning of the commissioning was important also from the commercial point of view.
  - Weekly plans on previous week
  - Daily plans on previous day

FINGRID

Forssa Fault Ride Through (FRT) test

- Forssa gas turbine FRT test was performed successfully on 18th September 2012
  - Both turbines were in operation, each with app. 120 MW
  - 3-phase 100 ms short circuit
  - Voltage in 110 kV busbar app 42%



Check list for preparation

- Arrangements to create the voltage dip needed and to clear the fault reliably.
- Stresses caused to grid components .
- Impacts on customers. Customer information .
- System security during the FRT test grid connection. Risk management.
- Protection during the FRT test connection, changes needed.
- Measurements.
- Personnel and communication during the test.

Aspects to be considered when preparing for commissioning and VJV tests

FINGRID

Tests during commissioning

- Tests to be performed during the commissioning period:
  - Tests that are part of manufacturers commissioning program
  - Tests required in VJV (Grid Code Specification for Power Generating Facilities)
- The size of the power plant has an impact on how to prepare for commissioning period


Source "TVO"

Commissioning of a large power plant - topics to consider

- Impacts on the grid in different operational situation (for example allowed voltage variation during tests, impact on the grid frequency, inertia, reserves)
- N-1 criteria: planned tests are not disturbances!
- Risks and risk mitigation during tests
- Timing of the tests
- Power trade, balancing – responsibility of power plant owner, but might have an impact on the grid
- Personnel during the tests, instructions, training of personnel
- Measurements
- Good co-operation with the power plant owner, communication between different parties during commissioning tests
- Information of other affected parties: market participants, neighbouring TSOs, customers, personnel, other affected stake holders

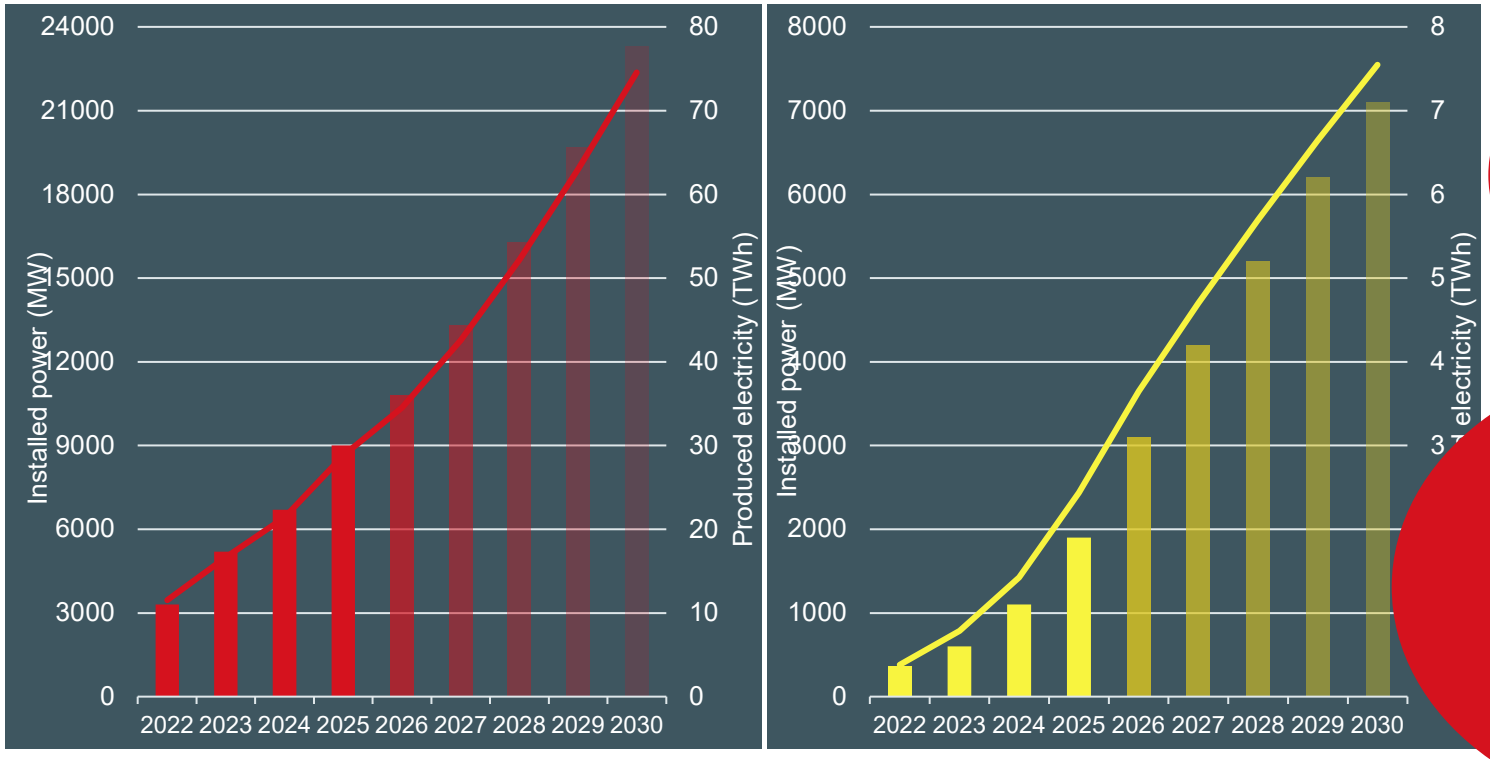

“Real tests are the only way to verify if the power plant complies with the requirements”
FINGRID

Developing requirements according to the observations

FINGRID

Growth of renewable converter connected production is accelerating

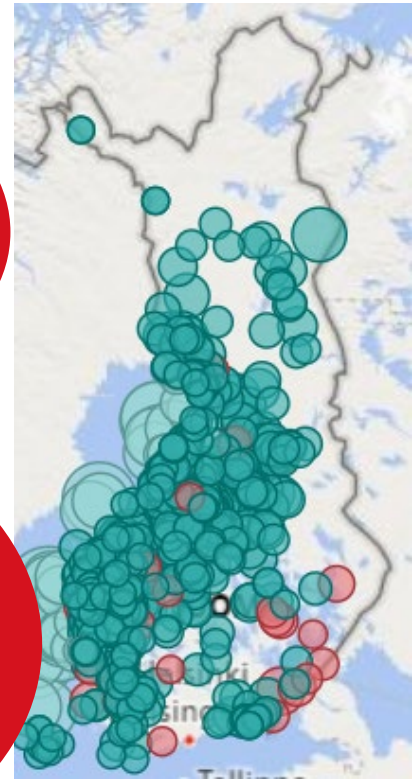
Estimate of wind and solar power development in Finland



Fingrid's Best Estimate

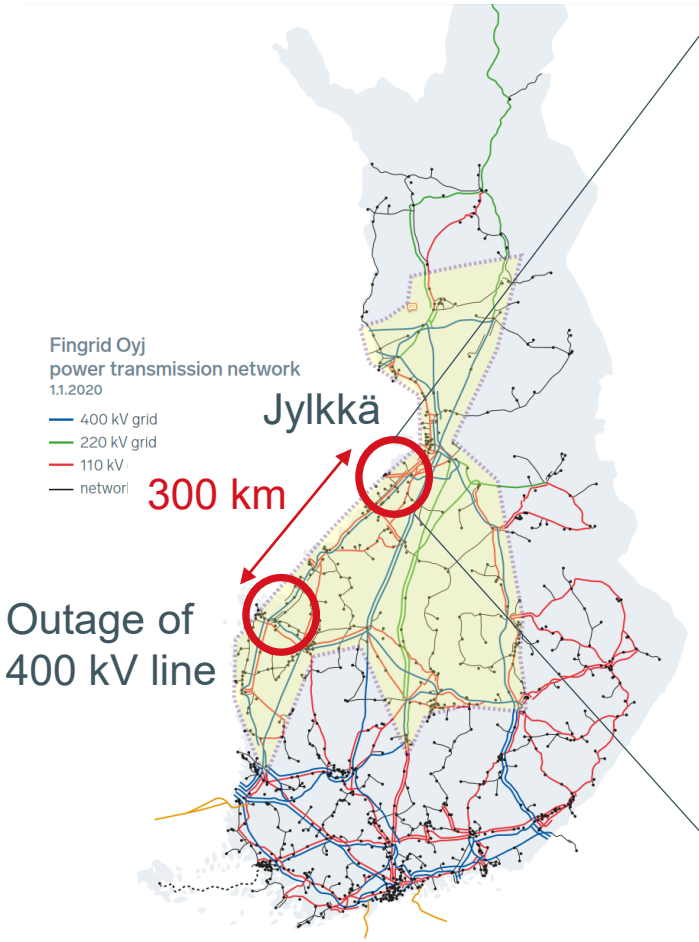
Number of synchronous generators is decreasing

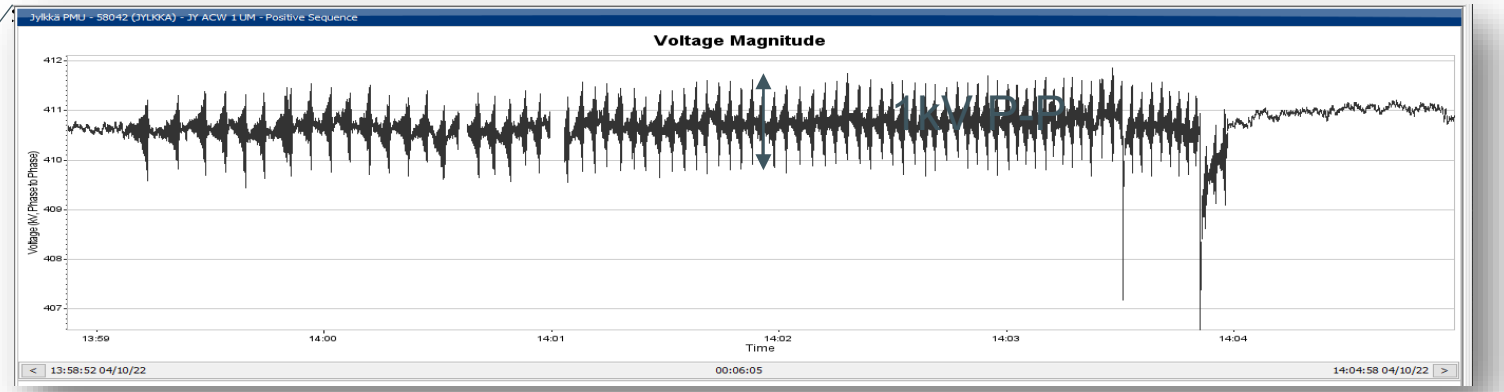
Especially wind power is concentrated in certain areas with less synchronous generators



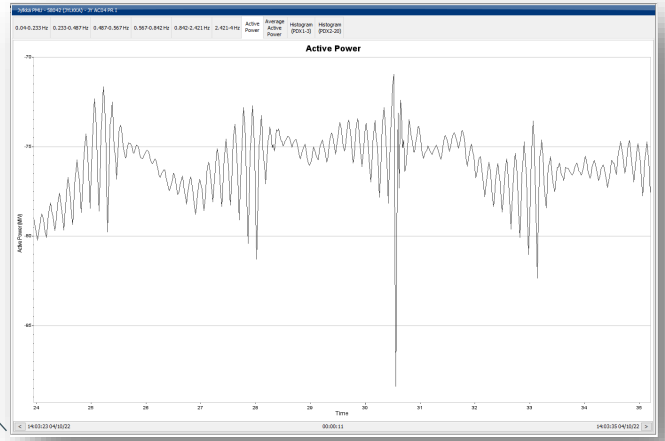
FINGRID

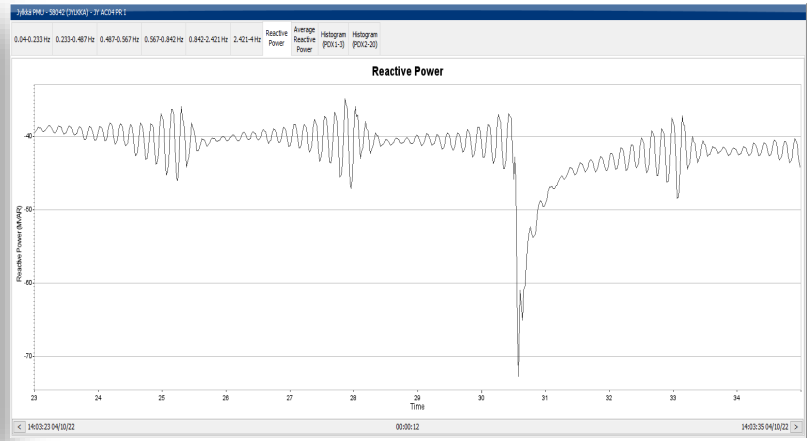
Voltage control instability on 4th October 2022





Jylkkä 400 kV voltage PMU measurement





Jylkkä 400 kV active and reactive power measurements

Specifications will be developed also according to observations

- Simulations will be even more important in future -> simulation models shall be accurate
  - It is difficult to create weak grid conditions for the testing, TSO need to trust on simulations
- It might be difficult to observe the voltage instability in control centre
  - Continuous recording will be required at D type power plants
- Requirements related to remote control will be tightened
  - Power plant control 24/7

➢ The preparation of new version VJV 2024 is in progress

FINGRID

Thank you.

Fingrid Oyj
Läkkisepäntie 21
FI-00620 Helsinki
P.O.Box 530
FI-00101 Helsinki, Finland
Tel. +358 30 395 5000
Fax. +358 30 395 5196

FINGRID