Compliance testing

- Requirements
- Testing vs Simulations
- Documents
- The Test Program
- Examples

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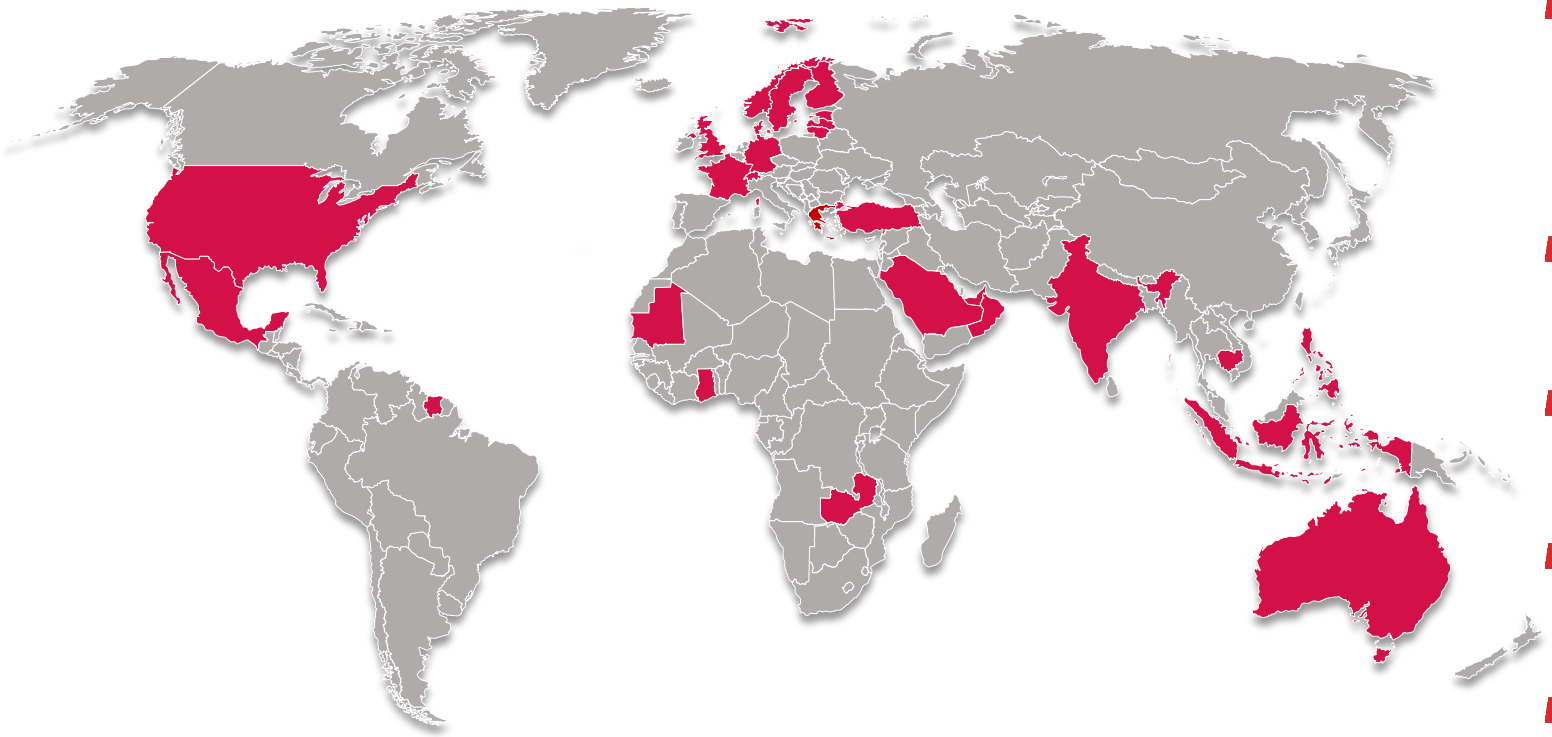
Providing reliable power to nations and industries



- Swedish engineering company
- 20 years
- 1000 projects
- 200 customers
- 25 countries

Requirements

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Why is there a grid code?

- Grid operation and production are separated in many countries
- The grid operator must rely on the production
- The production must rely on the grid
- Equal and predictable business for all producers

Requirements

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Why is there a grid code?

- Robustness – plants must stay in operation in difficult conditions to avoid blackout
- Controllability – the grid operator must be able to decide the operation according to grid demands
- Stability support – plants should help keeping the grid stable according to their ability or as per agreement

Requirements

Why is there a grid code?

- Safety – must limit operation to a safe range to protect the plant

- Safety – must disconnect if there is a serious problem, to protect both the grid and the plant from damage

..obviously, these requirements collide

Testing vs Simulation

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Some properties are better to simulate

- Often, an extensive simulation study is required before the plant is built
- Testing would risk damage – e g fault handling
- Testing would cause grid instability
- Testing would give dubious results – e g Power Quality
- Testing is practically impossible – lightning transients

Testing vs Simulation

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Some properties are better to test

- Testing may be required to confirm the simulation models
- Simulating would never cover everything – e g house load
- When external equipment is involved
- Functions that are critical for grid stability and should be double checked – e g excitation limiters
- Some properties may just be easier to test

Testing vs Simulation

but…

- There are things that can neither be simulated nor tested reliably, e g
  - Frequency range at full load
  - ROCOF capability

The Test Program

Purpose

- Describing how to perform the tests
- To be agreed upon by involved parties
- Often initiating the discussions – better early in the project
- Accepted by TSO as being sufficient for showing compliance – no further tests
- Accepted by supplier as being necessary for showing compliance – no less tests

The Test Program

Structure

- General test conditions
- Measurement/recording
- Description of each test
  - Conditions
  - Execution, step by step
  - Signals to be measured and sampling rate
  - Success criteria

Technical considerations

Signal preparation

- Shielded cables
- Shield grounded in ‘power plant’ end
- Avoid mixing signal types in one cable
- Exciter voltage/current may need filtering

Technical considerations

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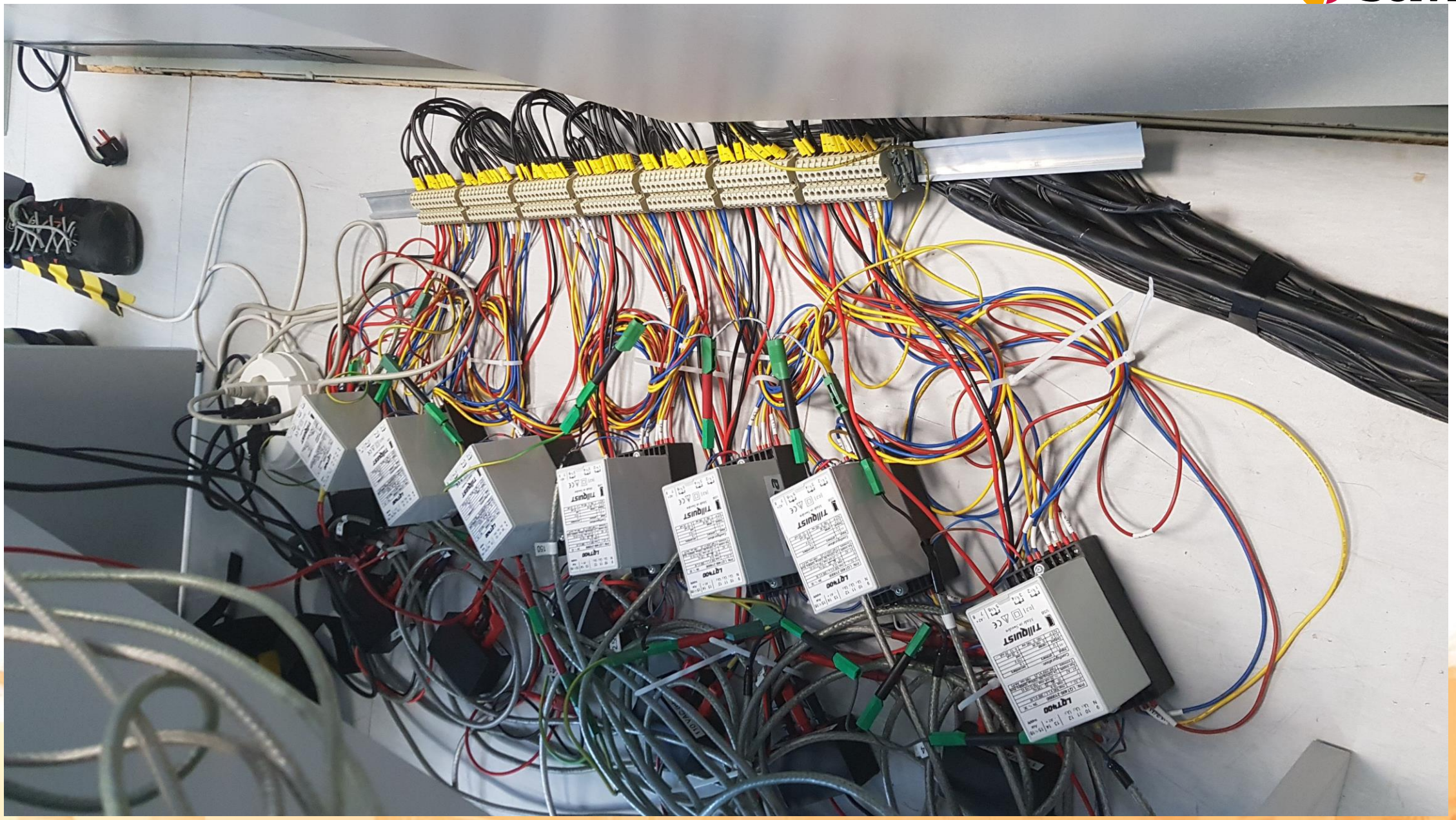

Technical considerations

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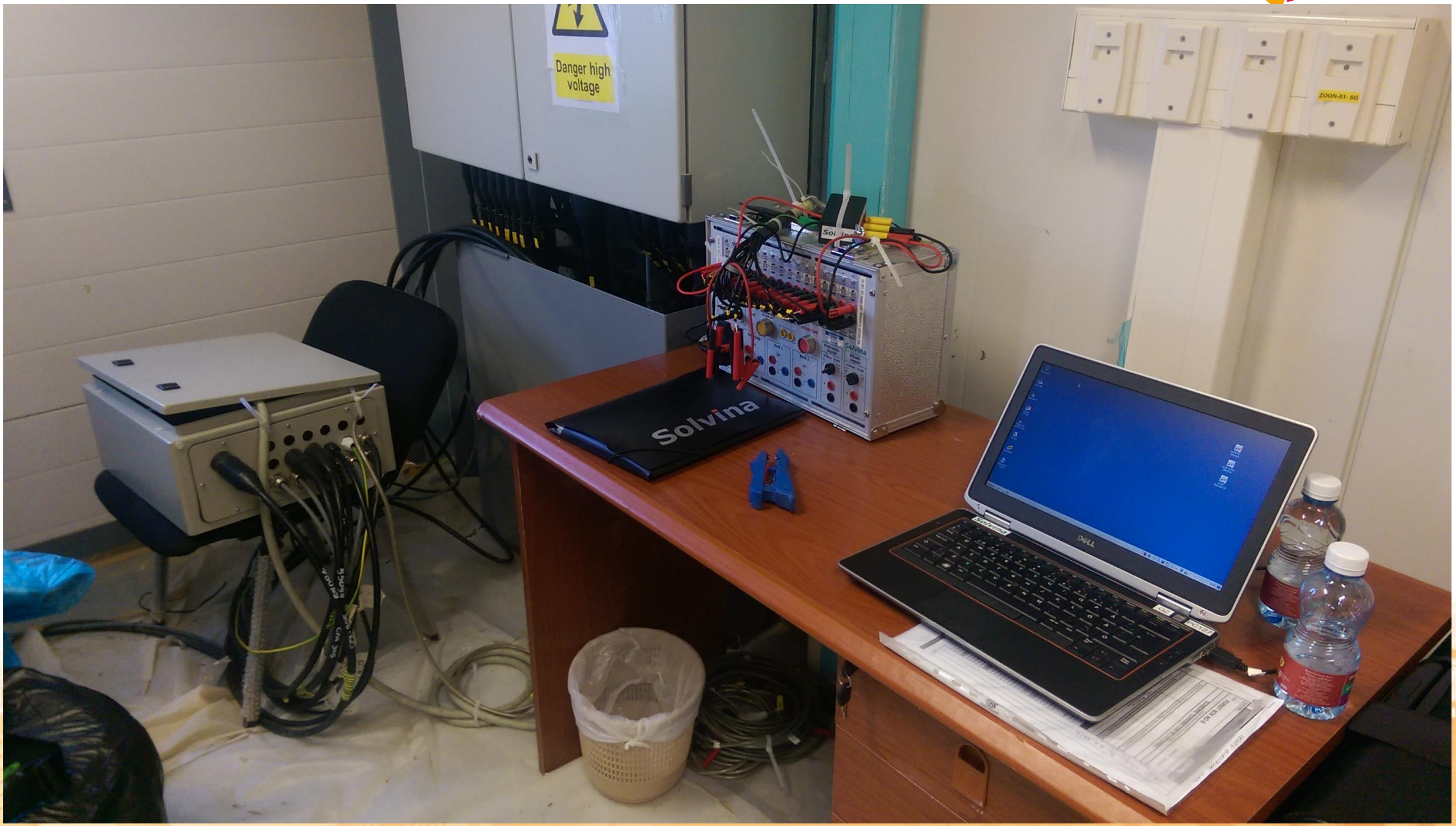

Test examples

Overall tests

- Load rejection
- House load
- Over/under frequency
- Over/under voltage
- Fault ride through
- Cold start & startups
- Black start
- Reliability
- Power quality

FRT

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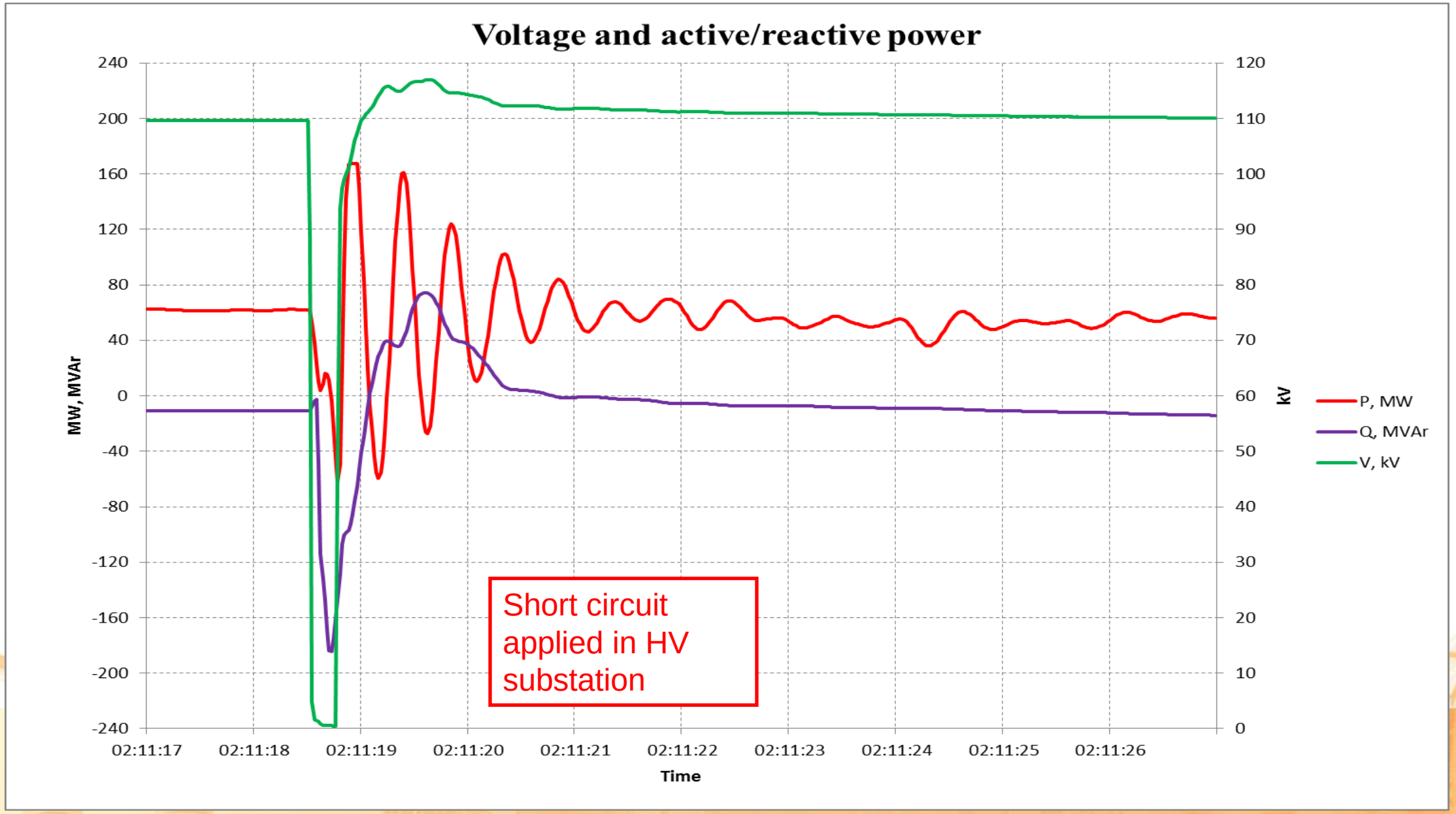
Voltage and active/reactive power
240
200
160
120
80
40
0
-40
-80
-120
-160
-200
-240
MW, MVAr
120
110
100
90
80
70
60
50
40
30
20
10
0
kV
02:11:17
02:11:18
02:11:19
02:11:20
02:11:21
02:11:22
02:11:23
02:11:24
02:11:25
02:11:26
Time
P, MW
Q, MVAr
V, kV
Short circuit applied in HV substation

FRT – compare to requirements

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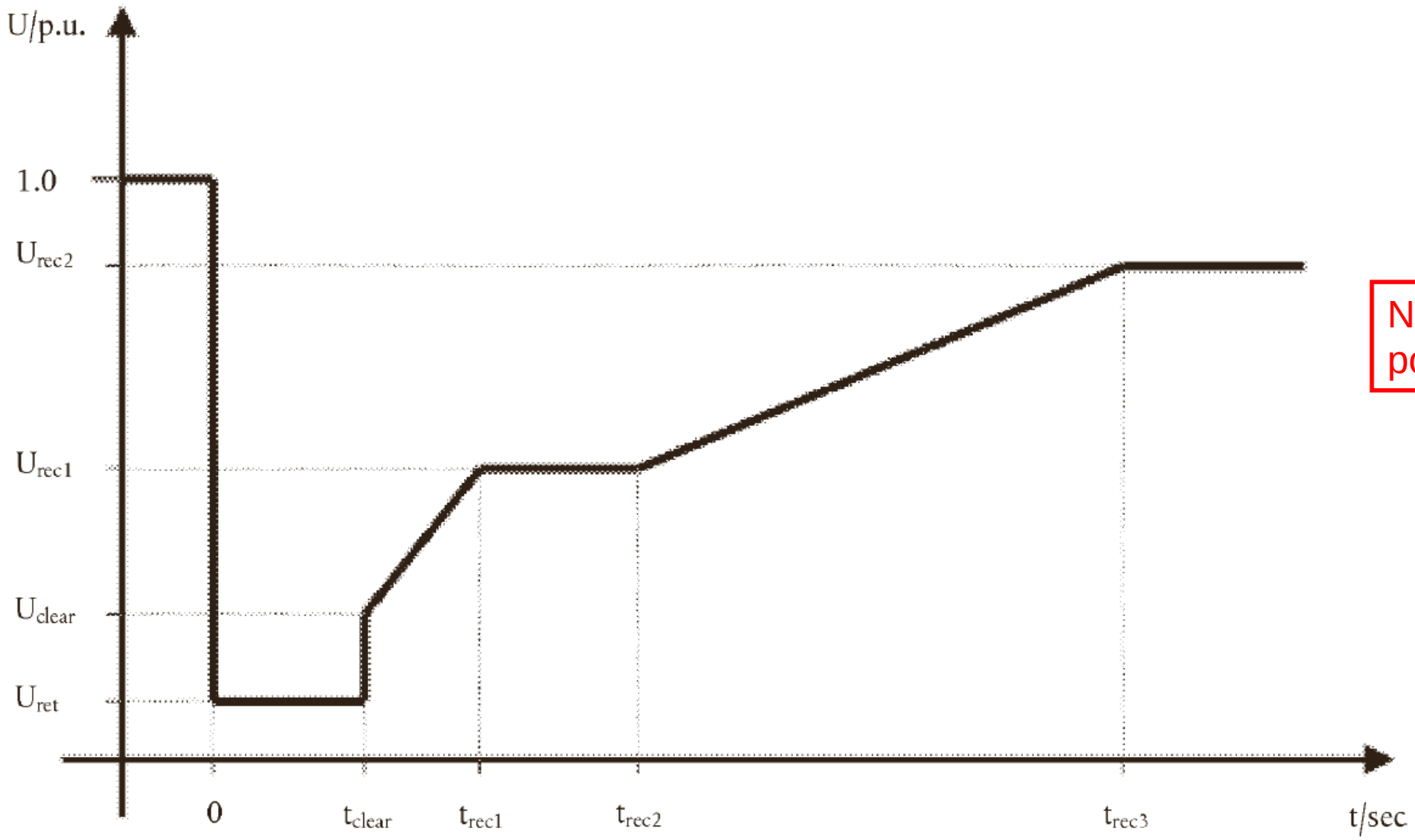
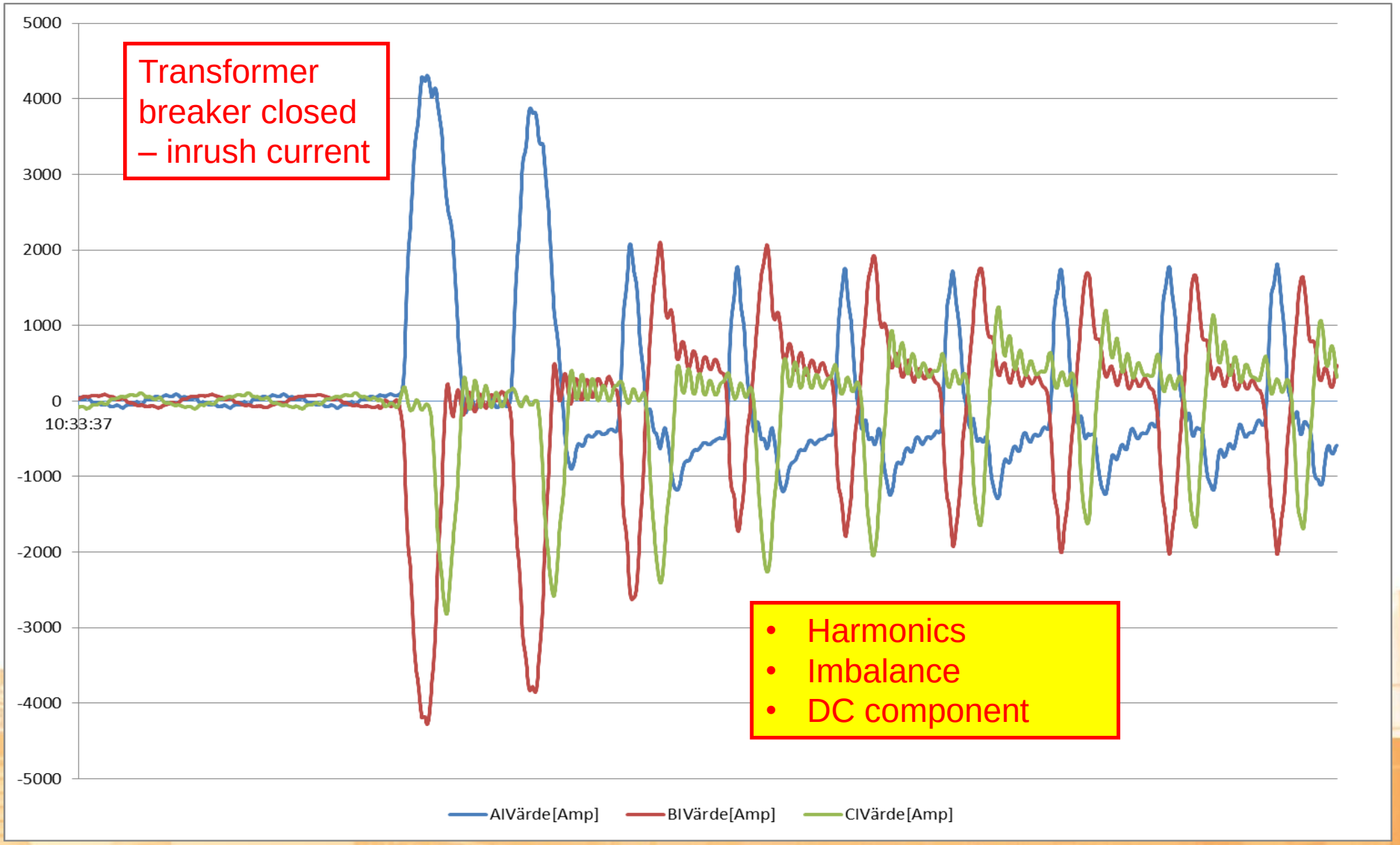
Fault-ride-through profile of a power-generating module

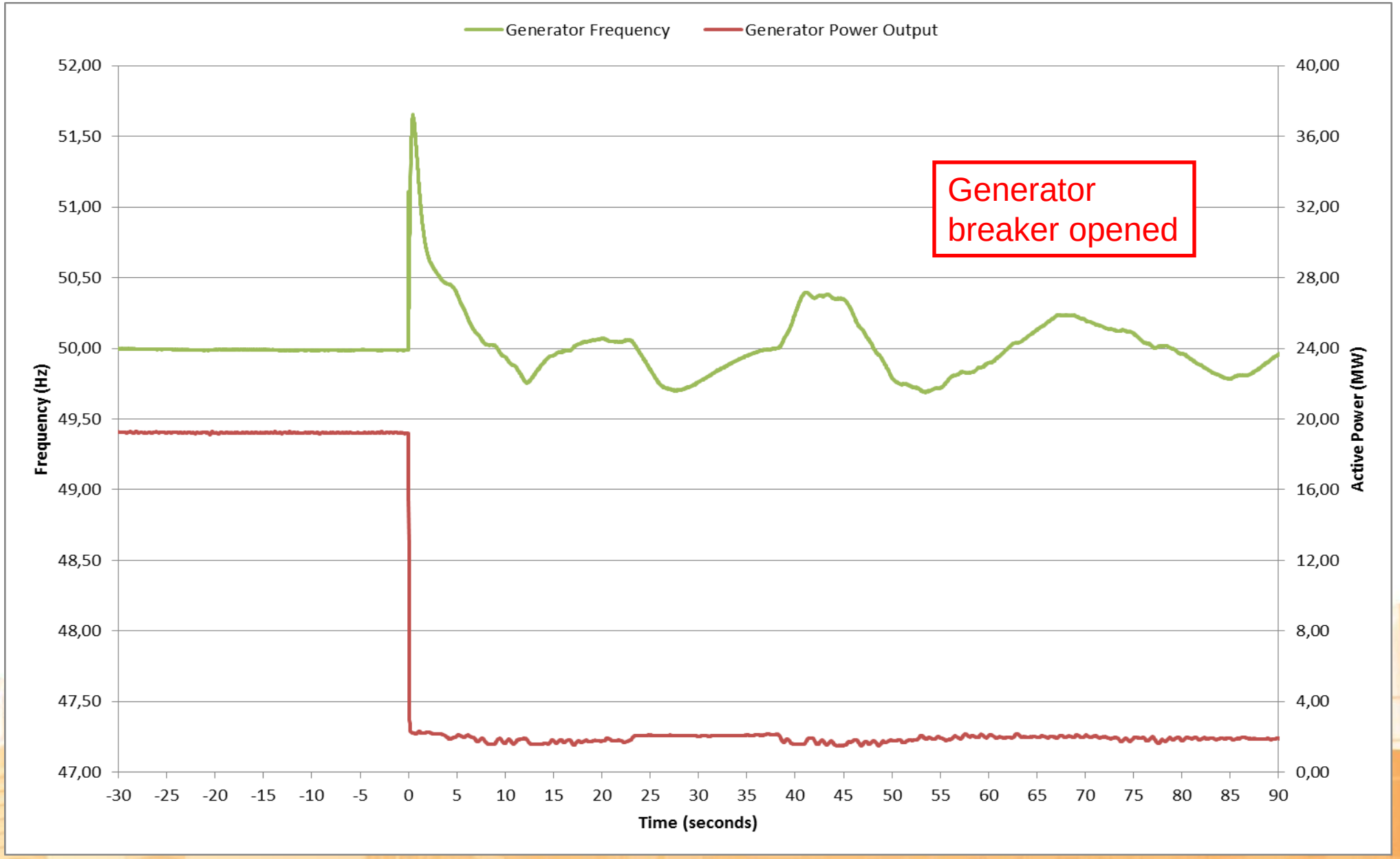


Not really possible to test

Black start – transformer energising



Load rejection & house load



Test examples

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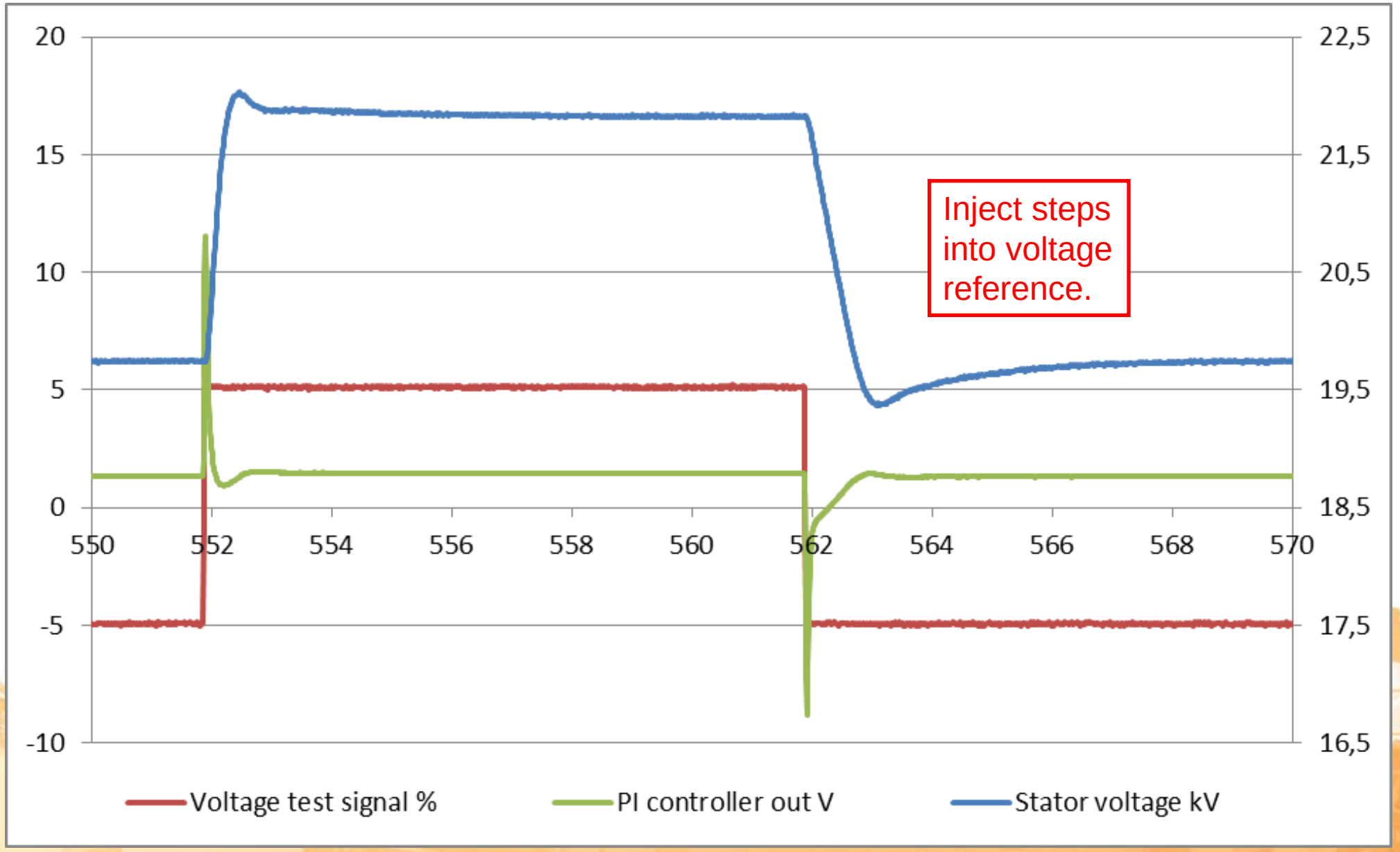
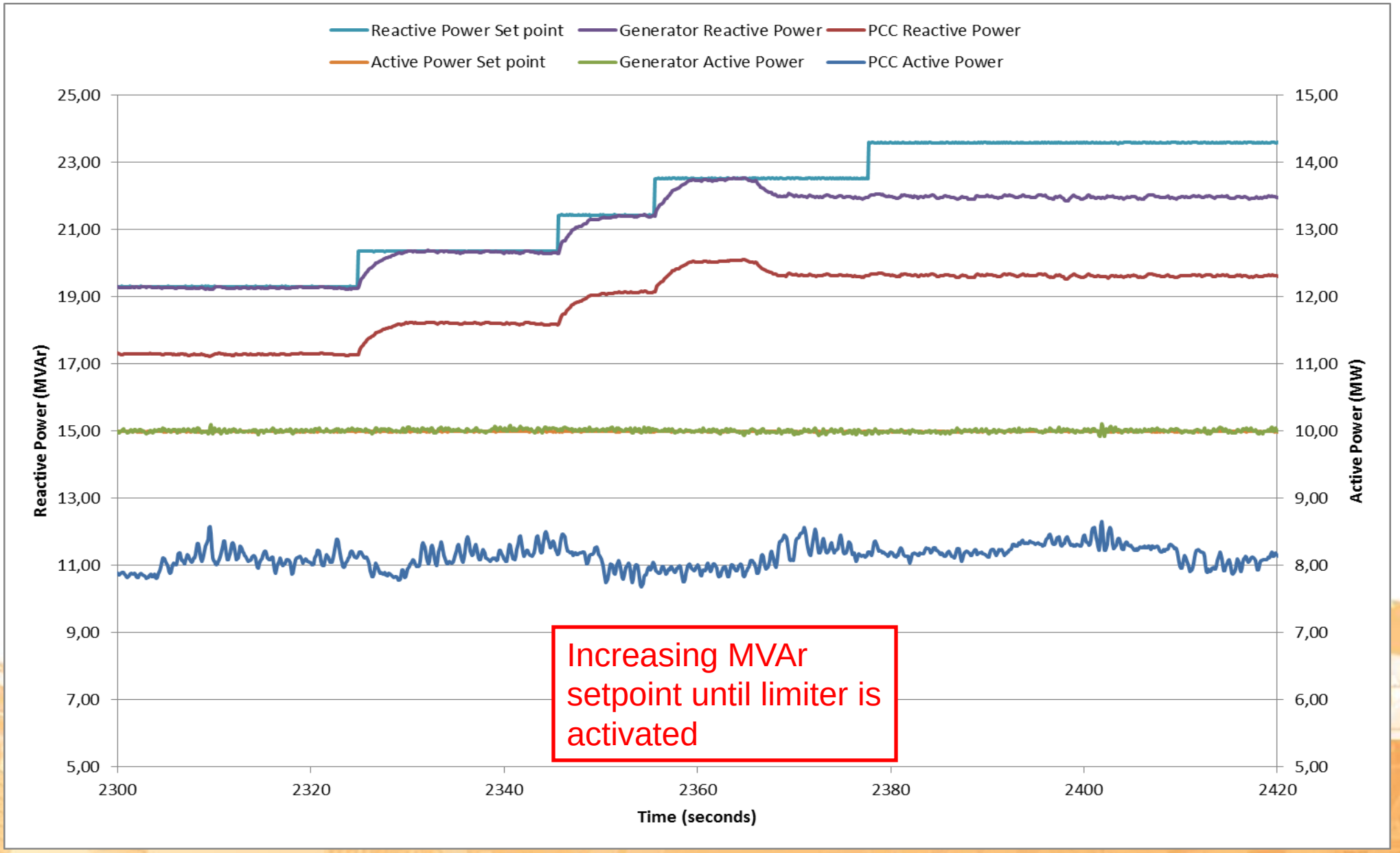
Excitation & generator tests

- Excitation response
- Excitation limiters
- PSS performance
  - On/off tests
  - Frequency response
- Voltage and reactive power control
- Reactive capability
- Generator data verification

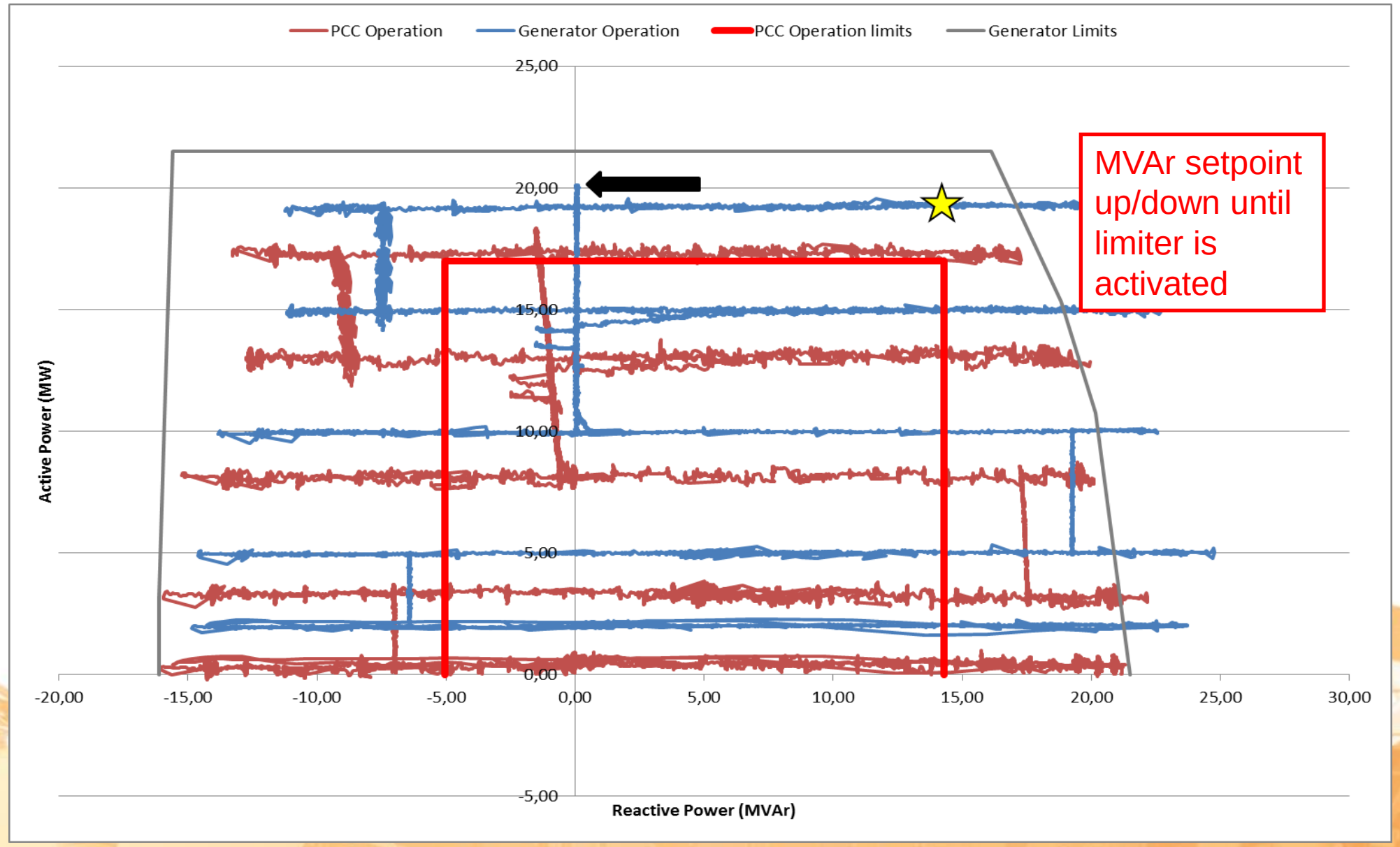
Excitation response



Excitation limiters



Reactive capability



Test examples

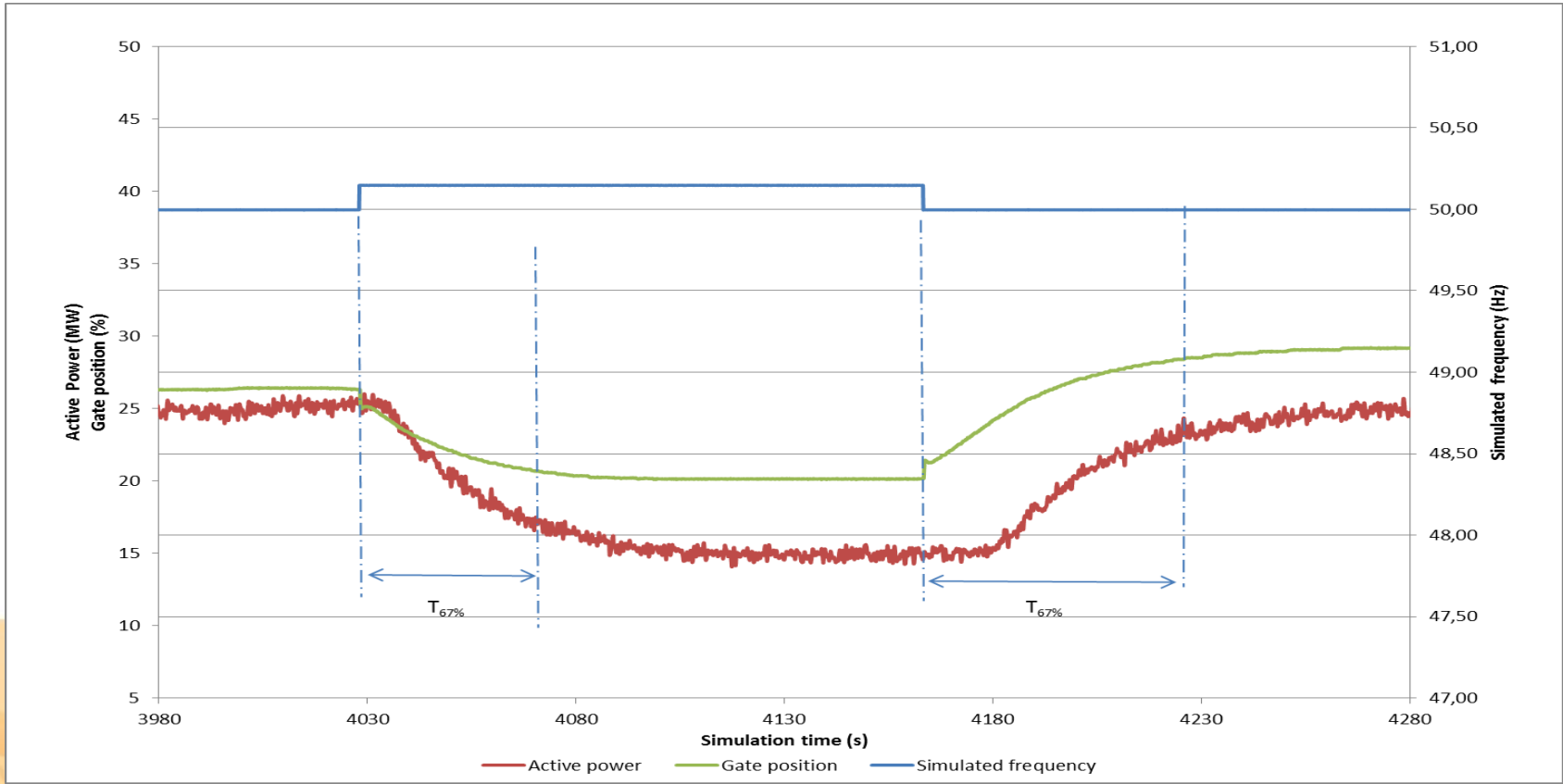
Governor & prime mover tests

- Power capability
- Power control
- Primary frequency response
- Frequency control
- Island operation
- Efficiency
- Fuel switching

Testing

Primary control

- Tested while grid connected
- Often a part of Grid code testing
- Apply a small step or ramp to the frequency
- Dynamics are seen poorly



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Island operation testing – general

- Run the unit (or plant) islanded
- Apply load steps up and down
- Record the frequency deviation
- From that, determine the permissible load step contained within a certain frequency range

Testing

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Load bank method

- Run the plant as an island, connected to a resistor bank
- Advantage: the plant is actually islanded, so all systems are included in the test
- Expensive and impractical method, in many cases also risky
- Not feasible for large plants
- Step size may be restricted

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Load bank method – this is what 16 MW looks like

Testing

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The Solvina method

- Run the plant connected to the main grid
- ...but replace the speed/frequency signal read by the governor
- Safe, flexible and inexpensive method

Testing

The Solvina method

- Actual turbine speed is not changed
- Island operation can be aborted at any time
- Governor tuning can be performed easily
- Find the limits and margins in a safe way
- Malfunctioning equipment can be identified

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Solvina method – this is what Hundreds of MW looks like

Testing

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Results

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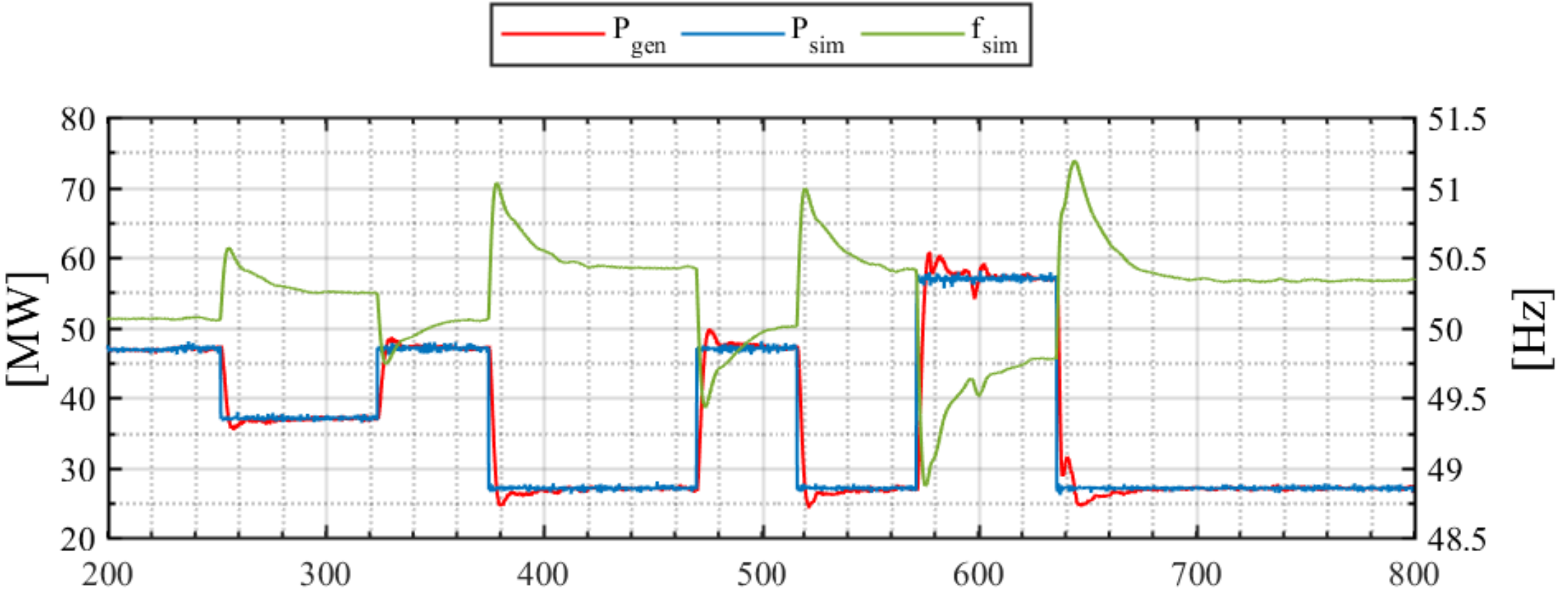
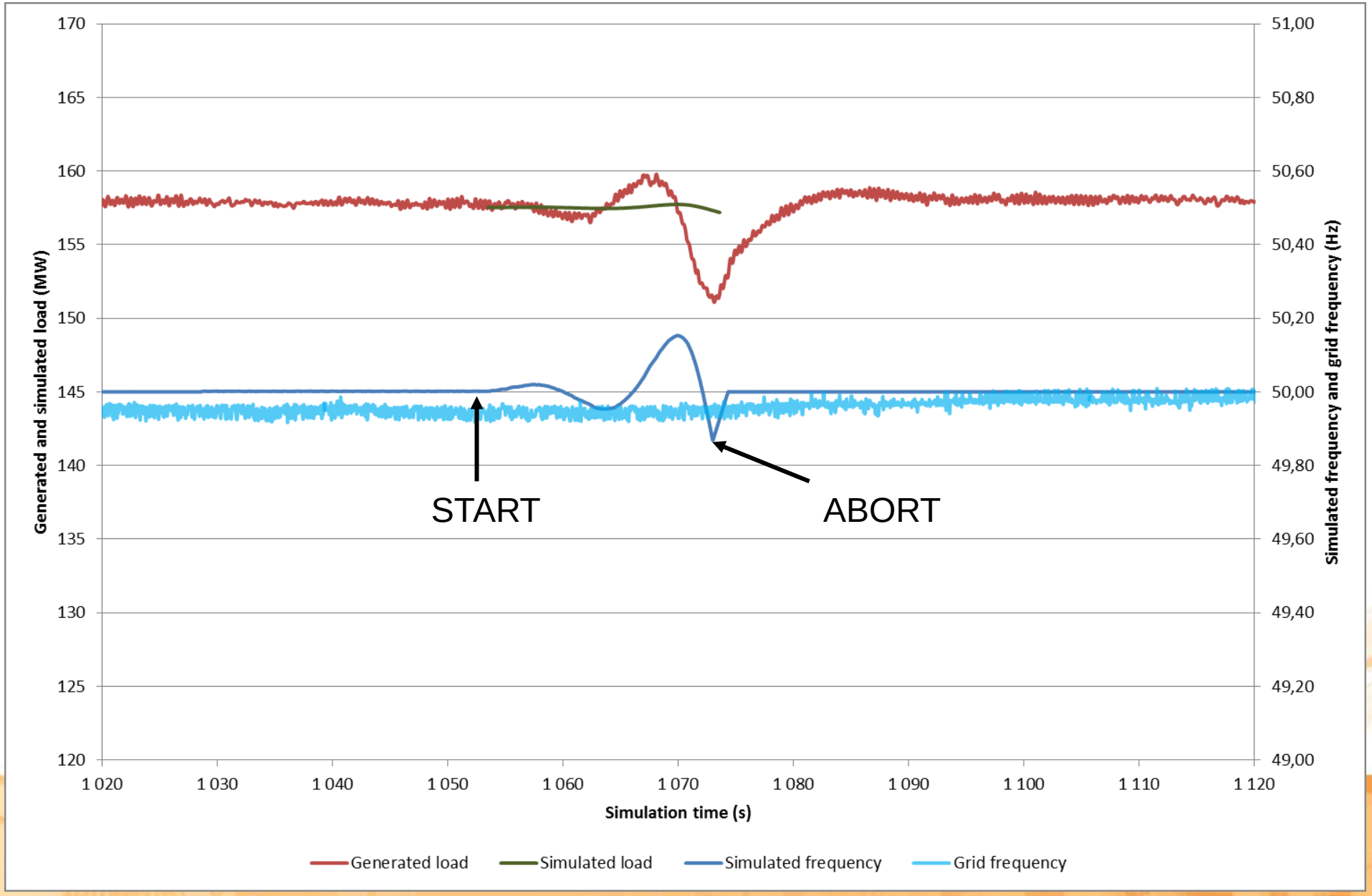
Finding plant capability



Results

Safety



Results

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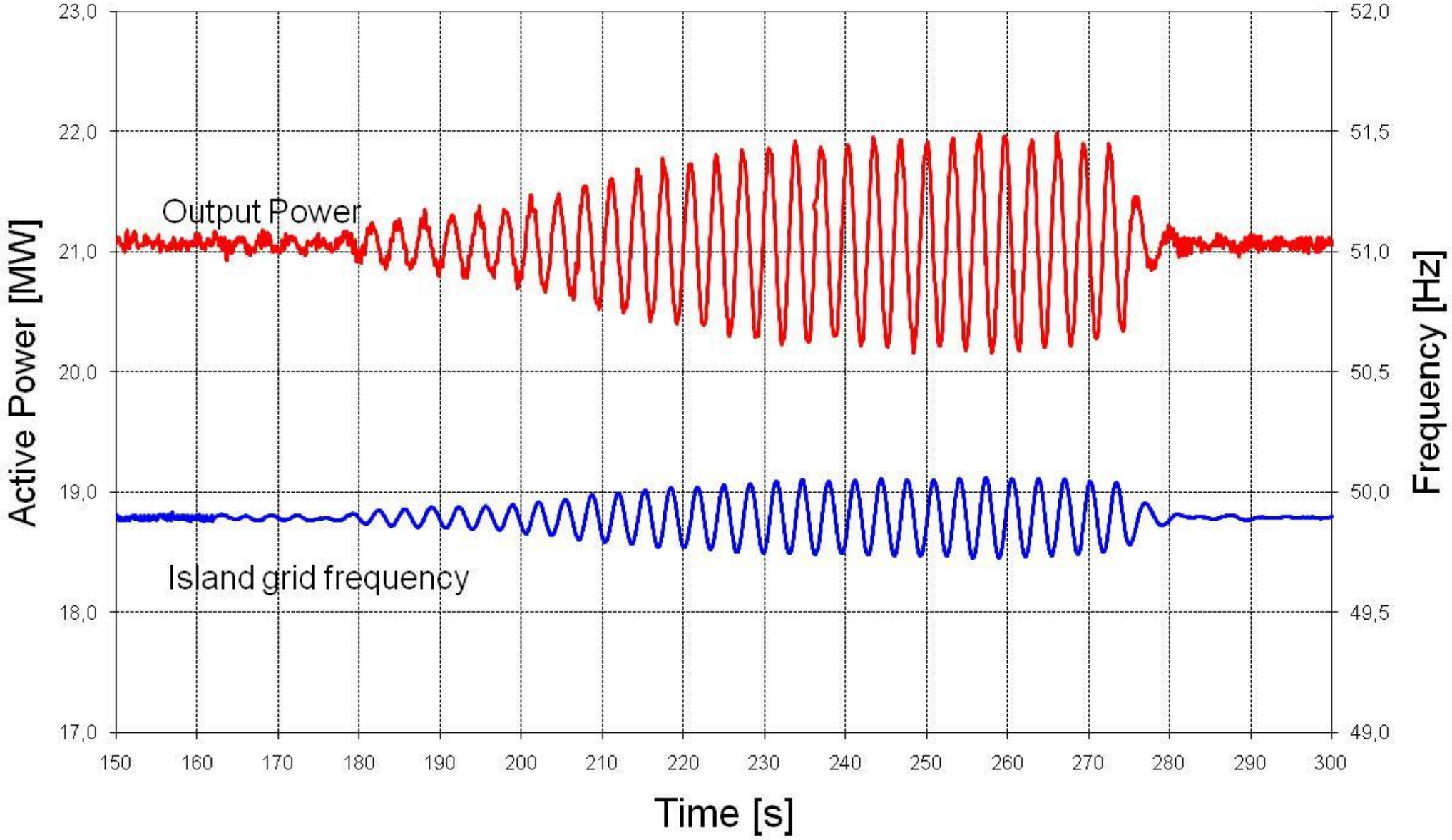
Tuning - before



Results

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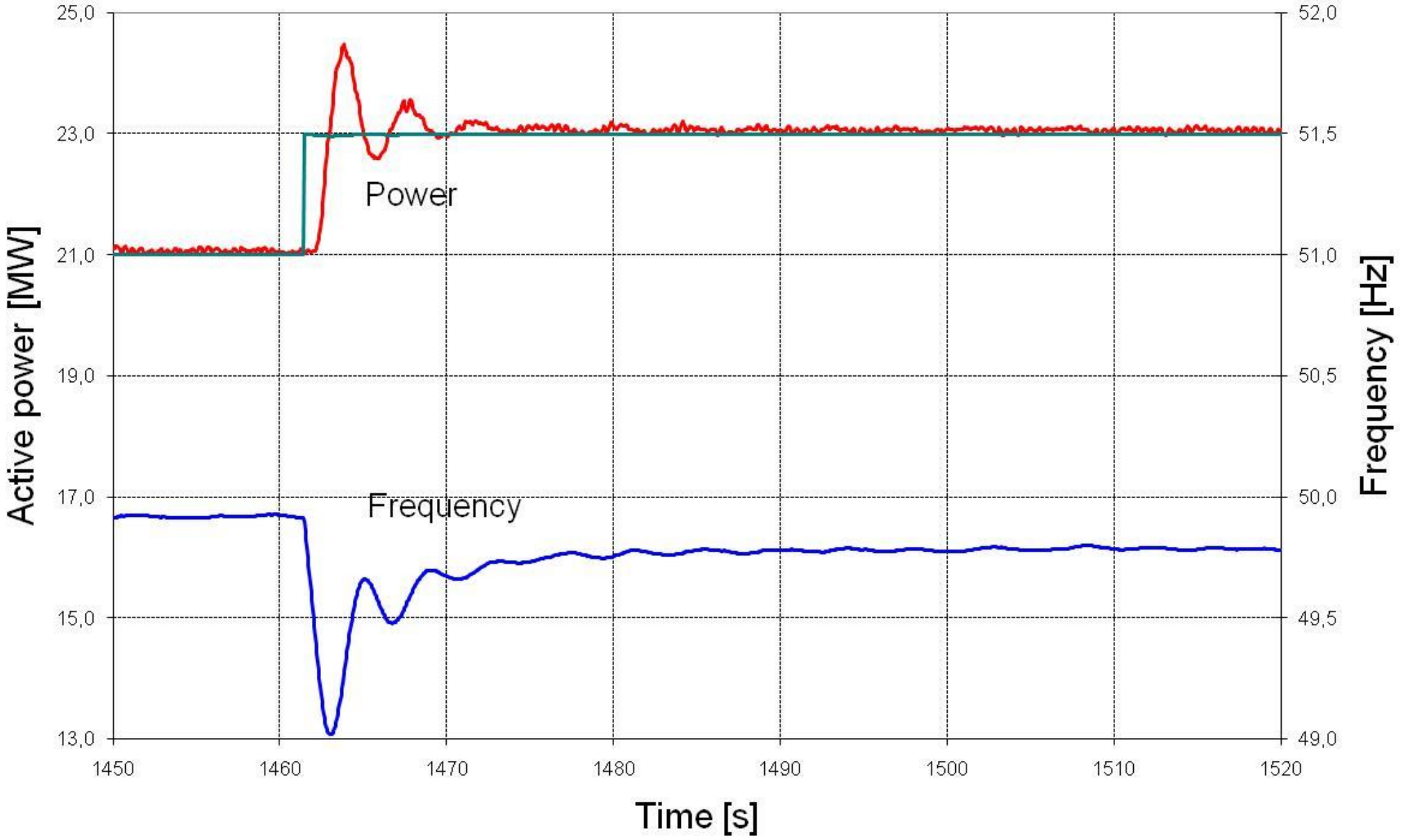
Tuning - after



Thank you for your attention

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