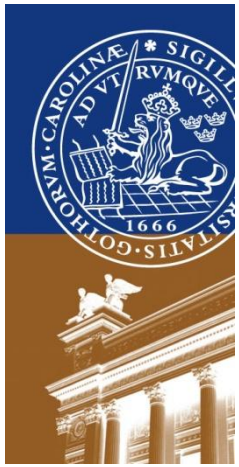

Island operation in Sweden – experience and studies

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Industrial Electrical Engineering and Automation

Why island operation field test?

- Fault clearing
  - Protection settings
    - Standard methods
- Frequency and voltage control
  - Parameter selection
    - Time simulations
  - Functioning of individual components
    - Limited field tests
    - Hardware-in-the-loop (Solvina)
  - Testing of complete system
    - Full-scale field test

River Ätran

- 50 kV network
  - Along river
  - Single infeed
  - Island operation backup
  - New generator controls
- Hydropower
  - 3+3x2+1 units = 57 MW
- Windpower
  - 8 units = 6 MW
- Customers
  - No interruption
- Sydkraft (E.ON) area
  - MV, LV, hydro

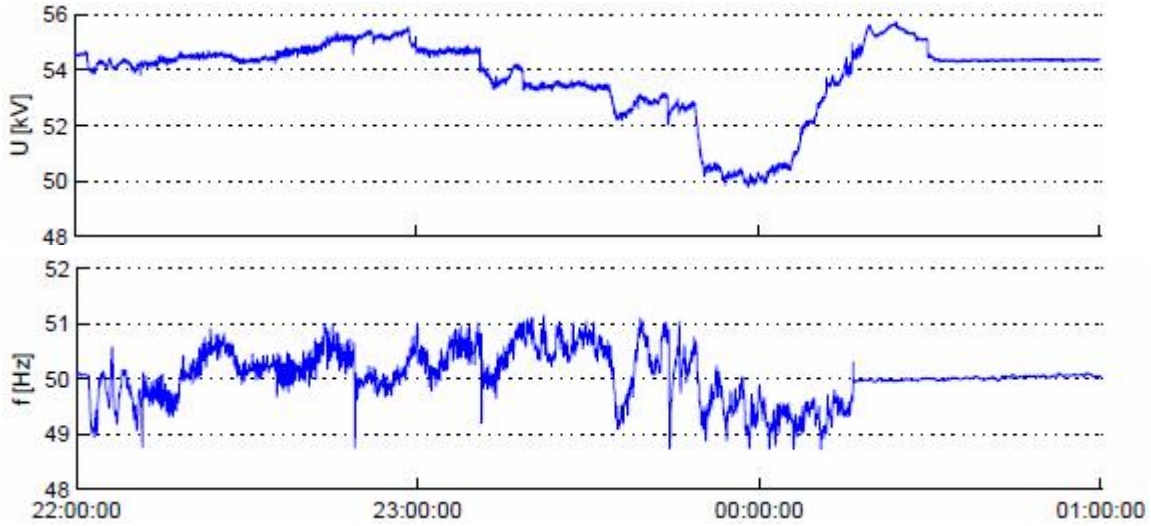
Ätran island operation field test – setup

- Monitoring
  - SCADA: event logs and minute/10 s data
  - PC data logger: kV, f, MW (G/T) and Mvar of tested units
  - 3 PMU: kV, generator currents, line currents
- 50 kV network
  - 15 MW load at starting of test an April night at 22.00
- Hydropower
  - 5 units with 30 MW capacity on-line
  - Check for limits in water flows and levels
- Windpower
  - All units on-line delivering 0,9 MW

Ätran island operation field test procedure

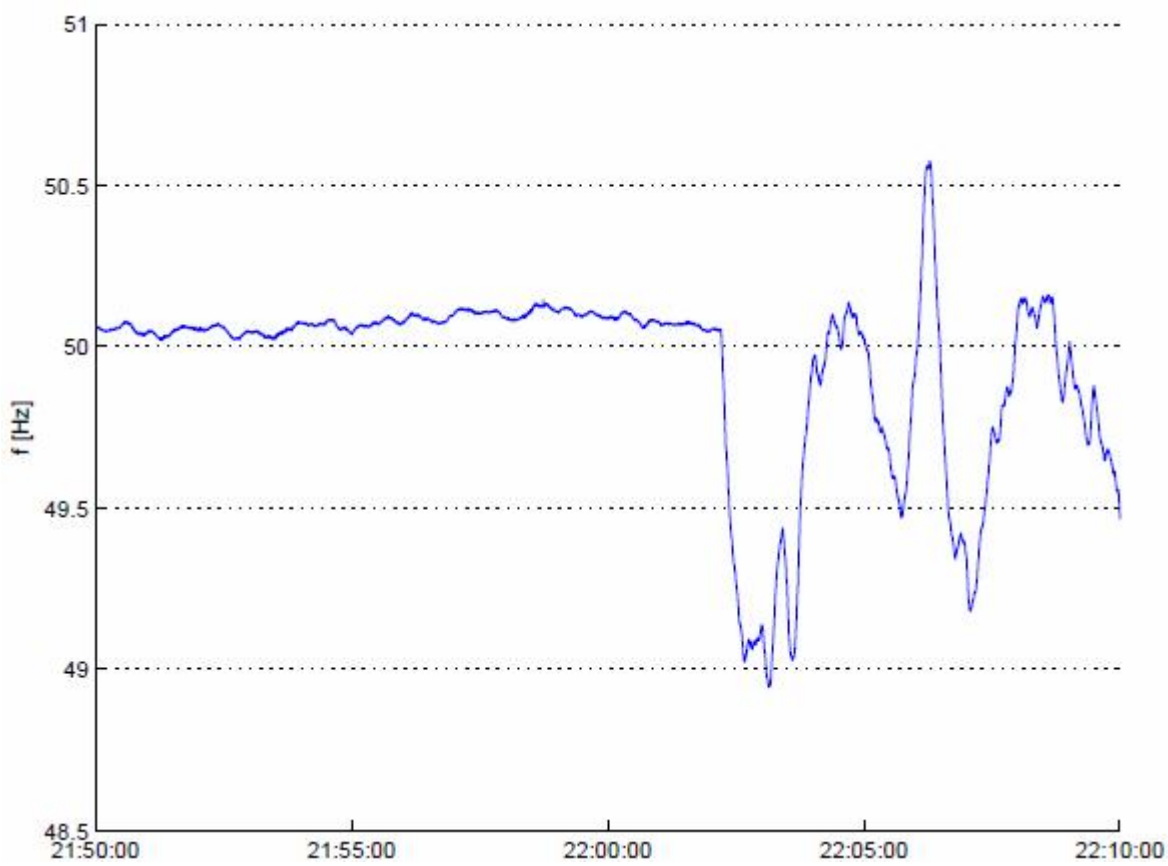
- Configure 50 kV network
- Start selected hydro units with some on manual
- Adjust hydro production for zero exchange with external network
- Open circuit breaker
- Run tests to assess f-control of test units G1, G2 and G1+G2
  - Manually change power level of one unit slowly
  - Trip one unit with 1 MW production
  - Trip one unit with 3 MW production
- Synchronize to external network

Ätran island operation: Result summary



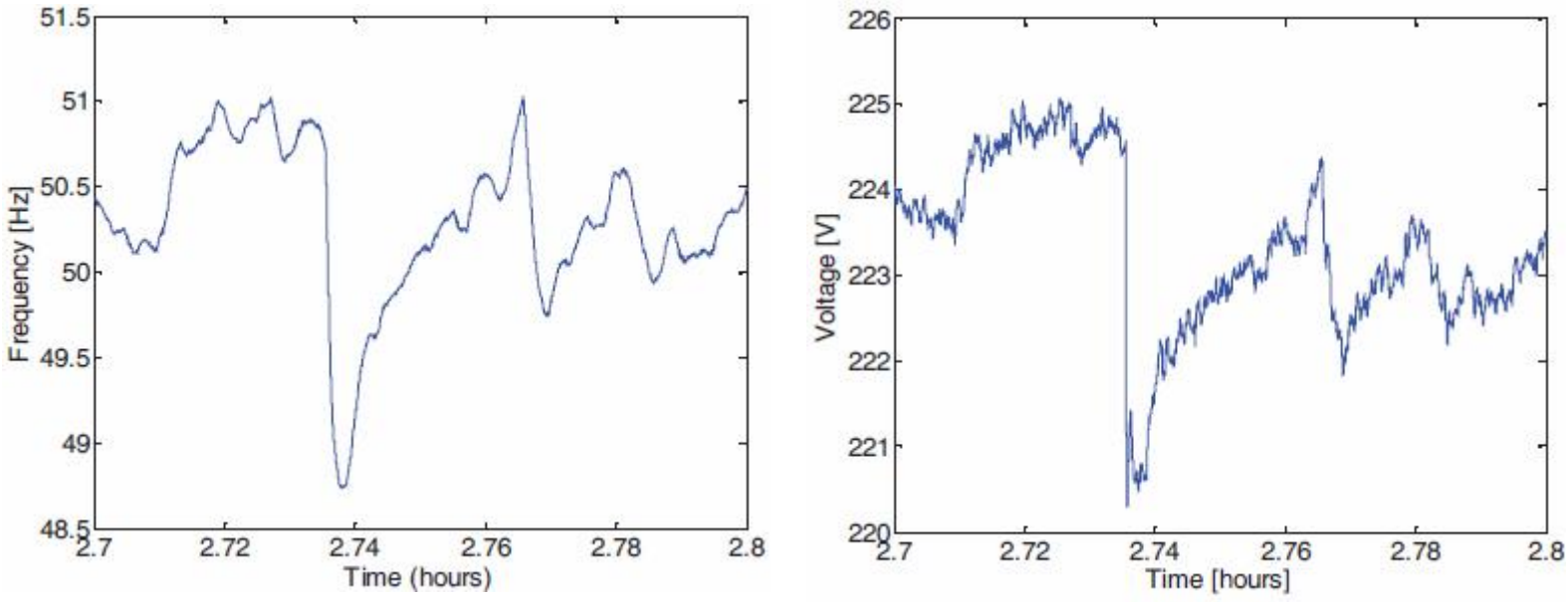
- Transitions to/from island operation OK
- Voltage and frequency OK
- Frequency control at tested G1 and G2
  - Worked fine when fully responsible
  - Poor sharing of MW
- Windpower tripped at 51 Hz
- MW oscillations at reconnection

Ätran island operation: Disconnection



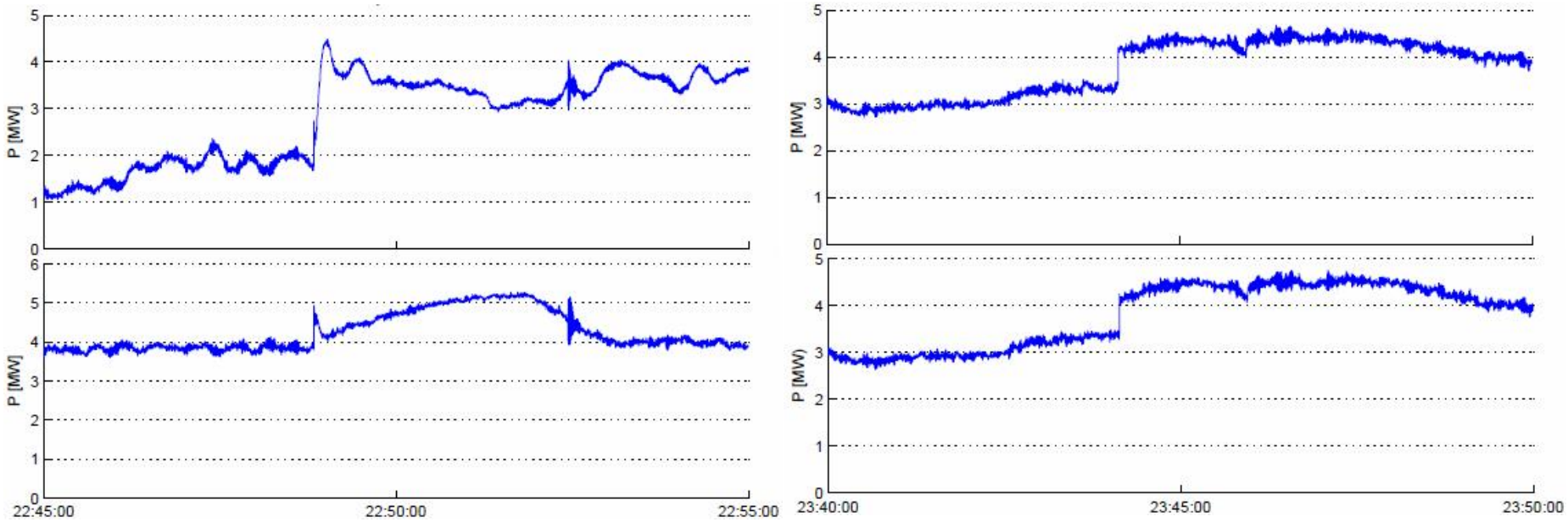
- Frequency drops to 49 Hz at transition to island operation

Ätran island operation: Voltage quality



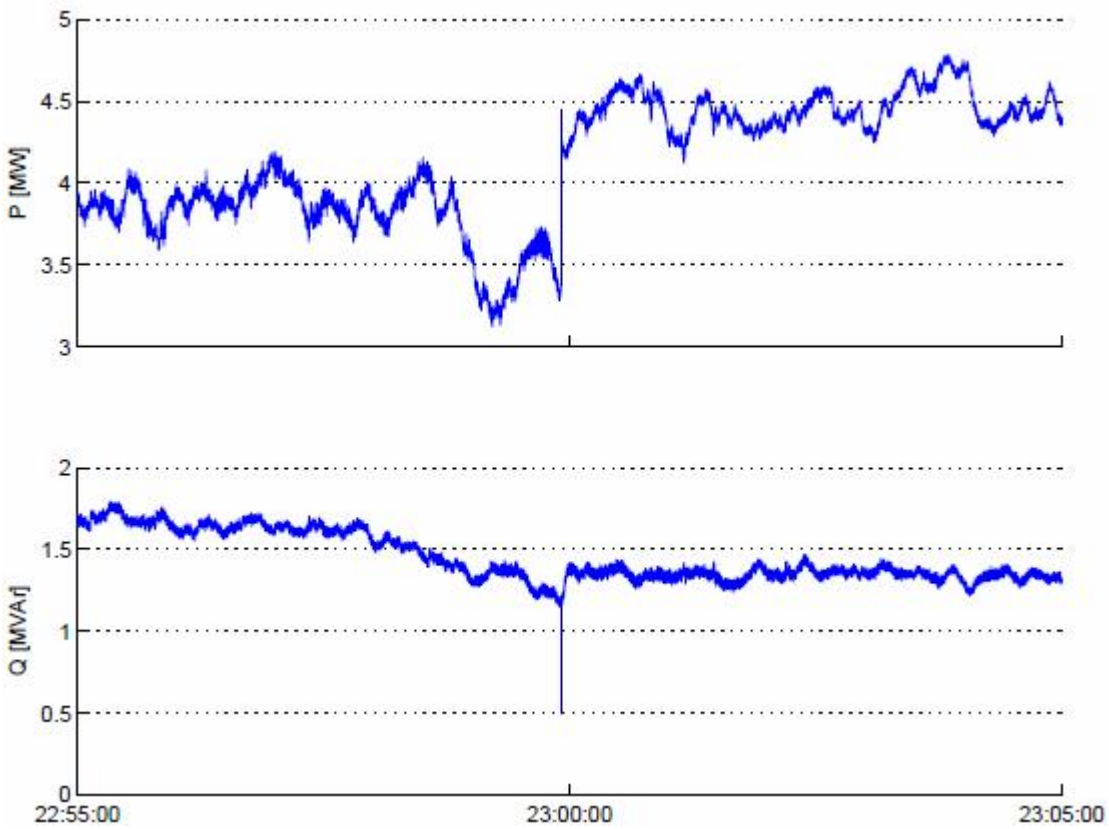
- Voltage follows frequency at trip of 2,2 MW unit
- Relative voltage drop about half frequency drop

Ätran island operation: MW sharing



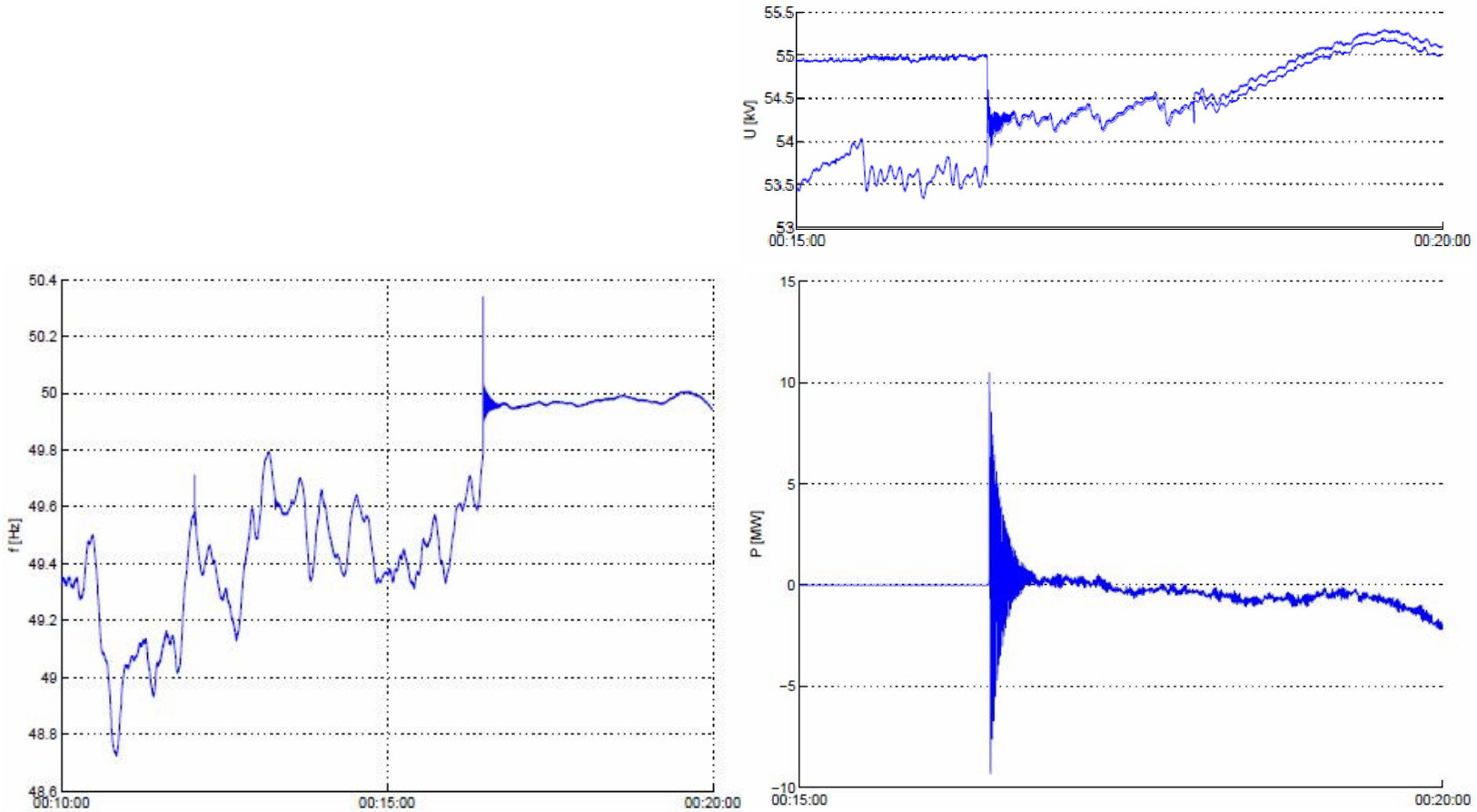
- Slow redistribution of MW between units participating in f-control
- Correct sharing between parallel units

Ätran island operation: Windpower trip



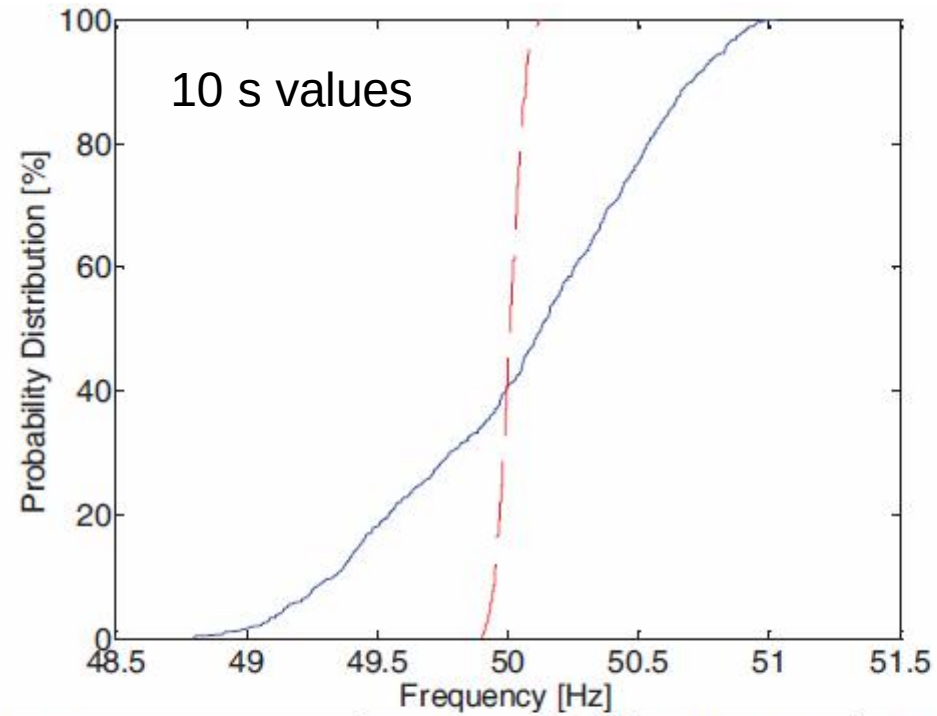
- Windpower trip at 51 Hz changes line flow

Ätran island operation: Reconnection



- MW oscillation at reconnection with Δf 0,2 Hz and Δv 0,5 kV
- Phase jump may affect ROCOF relays

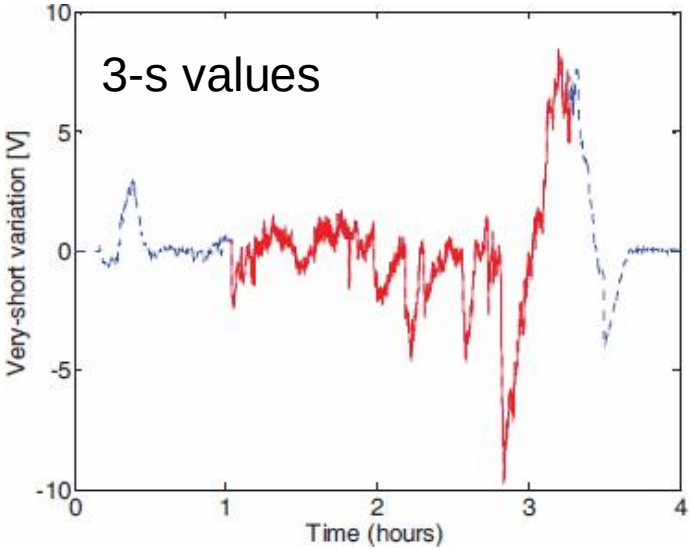
EN50160: Frequency



- Greater frequency variation during island operation
- Within limits
  - Only little margin
  - Time of events matters

Index	Grid-connected	Islanded	Objectives
Lowest frequency	49.76 Hz	48.80 Hz	47.5 Hz
Lower limit of 95% interval	49.92 Hz	49.07 Hz	49 Hz
Upper limit of 95% interval	50.08 Hz	50.89 Hz	51 Hz
Highest frequency	50.19 Hz	51.02 Hz	52.5 Hz

EN50160: Voltage



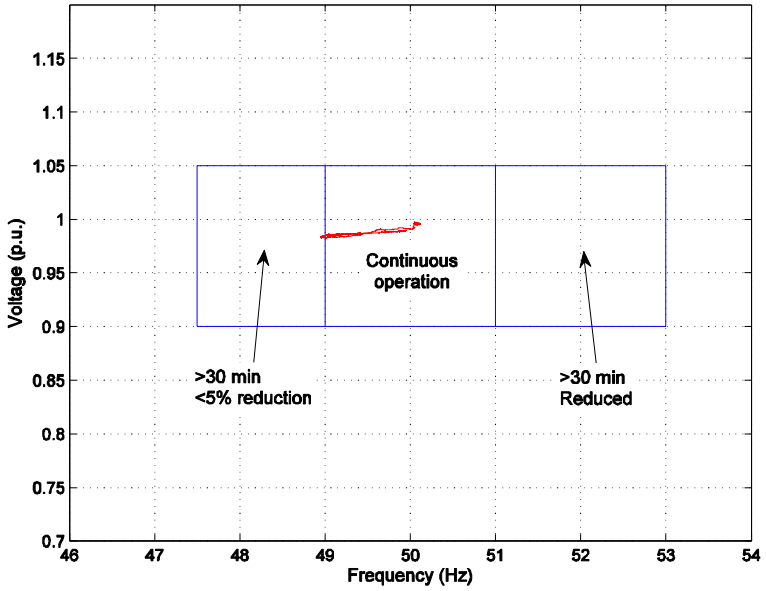
Index	Value (V)	Value (%)	Limit
Highest 10-min rms voltage	234.69 V	102%	110%
Lowest 10-min rms voltage	213.03 V	92.6%	85%
Lower limit 95% interval 3-second voltage	212.4 V	92.4%	85%
Upper limit 95% interval 3-second voltage	233.7 V	101.6%	115%
Lower limit 95% interval 1-minute voltage	212.4 V	92.4%	86%
Upper limit 95% interval 1-minute voltage	233.6 V	101.6%	114%
Highest 10-min very-short variation	6.7 V		2.5 V
Highest long-term flicker severity		7.2%	100%

- Greatest variations at end of test
- Events have great impact

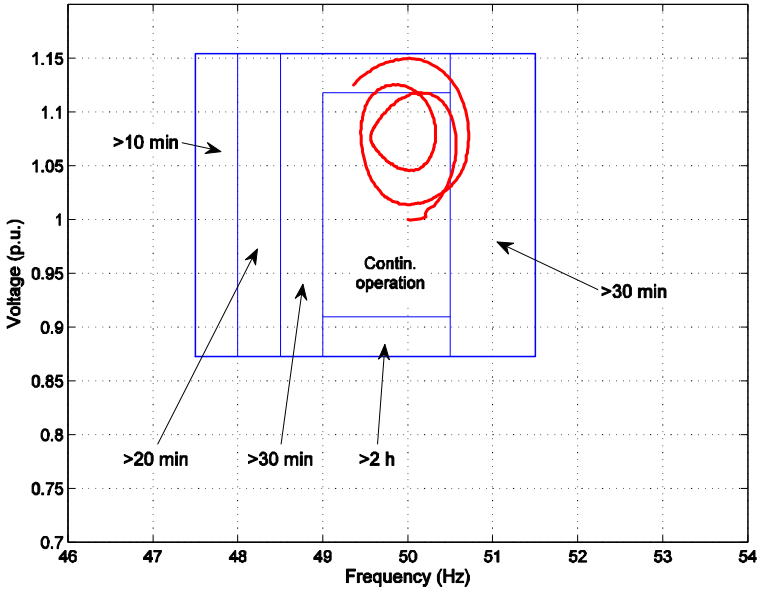
- No limits on instantaneous value

Protection against extreme V and f

Ätran data and Svenska Kraftnät requirements



Simulated data and E.ON requirements



- Conflict in settings range between dependability and robustness
  - Narrow to permit islanding detection
  - Wide to permit grid fault ride-through as required by TSO

Backup generators in cable networks

- Backup generators normally used in OHL networks
  - Reactive power injected to keep voltage high enough
- Rural OHL networks replaced by extensive cable networks
  - Considerable charging capacitance
  - Question is how to keep voltage low enough
- Cable failure infrequent but may be long
  - Clear application of backup generators
  - Backup generators need to absorb reactive power

References

M. Bollen, O. Samuelsson, “Controlled island operation of part of the 50-kV grid in Southern Sweden,” IEEE Power Tech 2009, Bucharest, Romania, 28 June-2 July 2009.

M. Bollen, J. Zhong, O. Samuelsson, J. Björnstedt, “Performance indicators for microgrids during grid-connected and island operation,” IEEE Power Tech 2009, Bucharest, Romania, 28 June-2 July 2009.

O. Samuelsson, N. Stråth, “Islanding detection and connection requirements”, IEEE General Meeting 2007, 24-28 June, Tampa, FL, USA.

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