Contents

TEST 1: Measurements for determination generator parameters (can be replaced with factory acceptance tests)

1. Open circuit saturation

Scope of the test

Scope of the test is to measure the generator no load characteristic.

Test conditions

Generator circuit breaker is opened.

Success criteria(s)

Generator no load characteristic is measured and plotted.

Recorded signals

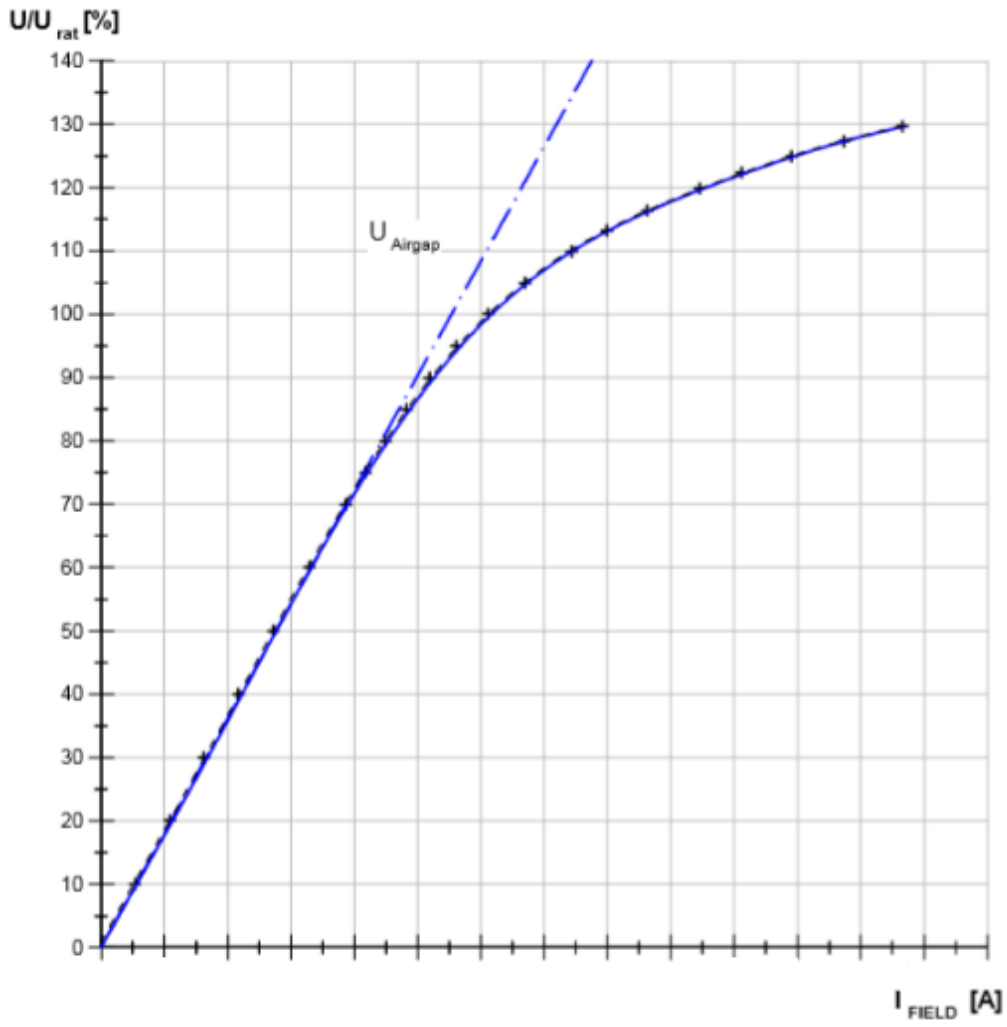
U, I_{field}, U_{field}, UL1-L2, UL2-L3, UL3-L1

Test Results

No load characteristic *(X – deleted by Elering, but shown by the Client)*

U/Urat [%]	UL1-L2 [V]	UL2-L3 [V]	UL3-L1 [V]	U [V]	PLOSSES [kW]	IFIELD [A]	UFIELD [V]
129,7	X	X	X	X	X	X	X
127,3	X	X	X	X	X	X	X
124,9	X	X	X	X	X	X	X
122,3	X	X	X	X	X	X	X

119,9	X	X	X	X	X	X	X
116,3	X	X	X	X	X	X	X
113,2	X	X	X	X	X	X	X
109,9	X	X	X	X	X	X	X
104,9	X	X	X	X	X	X	X
100,1	X	X	X	X	X	X	X
95,0	X	X	X	X	X	X	X
90,0	X	X	X	X	X	X	X
84,9	X	X	X	X	X	X	X
79,9	X	X	X	X	X	X	X
75,0	X	X	X	X	X	X	X
69,9	X	X	X	X	X	X	X
60,1	X	X	X	X	X	X	X
50,0	X	X	X	X	X	X	X
40,0	X	X	X	X	X	X	X
30,0	X	X	X	X	X	X	X
20,1	X	X	X	X	X	X	X
10,0	X	X	X	X	X	X	X
0,2	X	X	X	X	X	X	X



No load characteristic

2. Saturation factors

Scope of the test

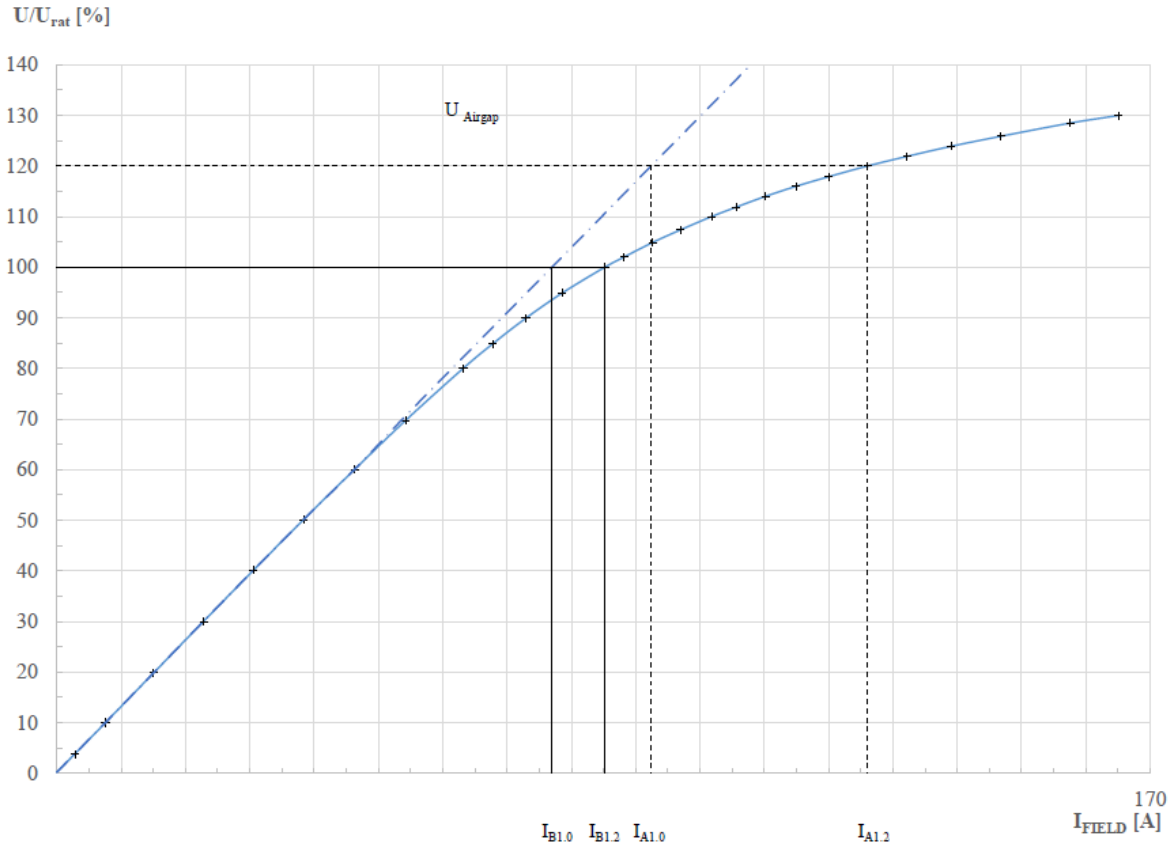
Scope of the test is to measure no load characteristic and calculate saturation factors S1.0 and S1.2Test conditions

Success criteria(s)

Recorded signals

Test Results

FIGURE 1. Determination of saturation factors' S1.0 and S1.2 parameters



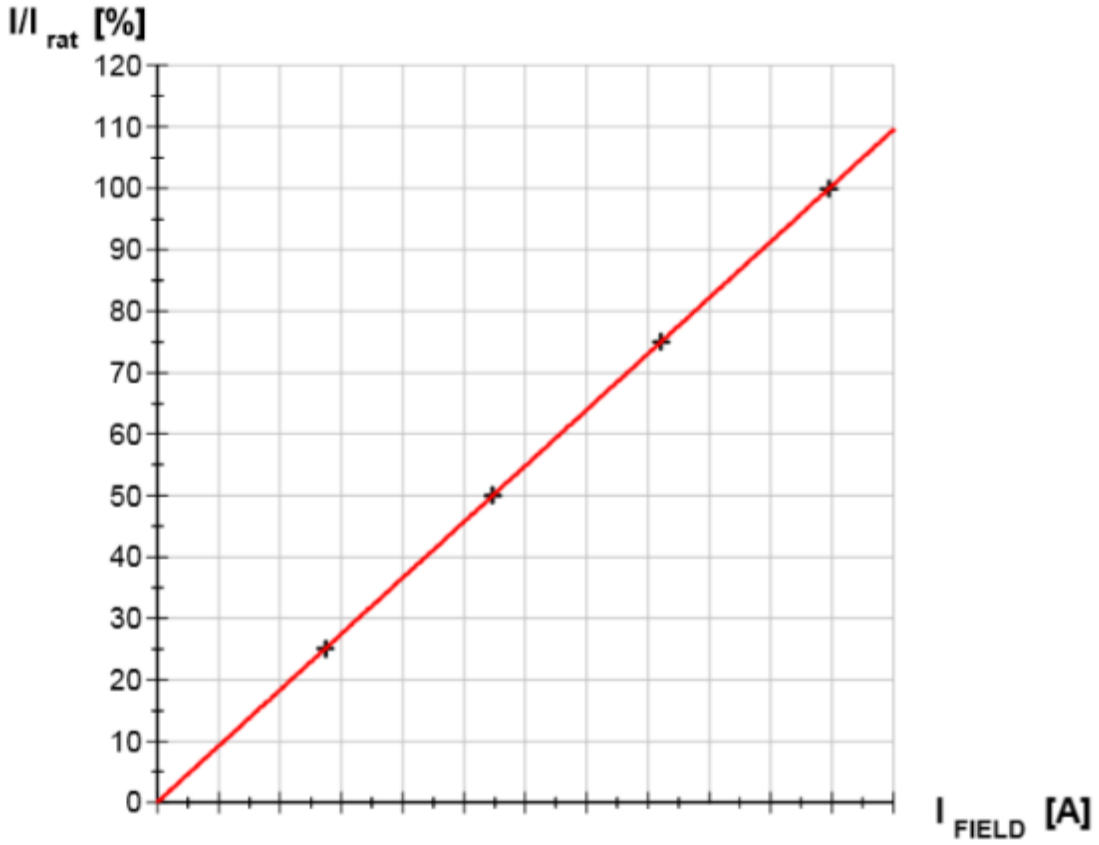
$$S_{1.0} = \frac{I_{A1.0} - I_{B1.0}}{I_{B1.0}} \qquad S_{1.2} = \frac{I_{A1.2} - I_{B1.2}}{I_{B1.2}}$$

Saturation factors: S1.0= S1.2=

No-load-/ short-circuit ratio

3. Short circuit load test

I/Irat [%]	I1 [A]	I2 [A]	I3 [A]	I [A]	IFIELD [A]	PLOSSES [kW]
124,93					X	
99,99					X	
75,06					X	
50,04					X	
25,07					X	
0,07					X	



Short circuit characteristic

TEST 2: Power quality measurements

Flicker (95 % of the measured values in 1 week)

	Measured	Allowed (110 kV)	Allowed (330 kV)
P_{st}			
P_{lt}			

Harmonics (95% of the measured values in 1)

	Measured	Allowed (110 kV)	Allowed (330 kV)
THD U ()			
TDD			

Harmonics	Measured *Relative voltage u_h, %*	Allowed (110 kV) *Relative voltage u_h, %*	Allowed (330 kV) *Relative voltage u_h, %*
2			
3			
4			
5			
6			
7			

8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			
33			

34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			

Asymmetry (during 1 week measuring 95 % of the cases)

	Measured, %	Allowed (110 kV), %	Allowed (330 kV), %
k_a			

Table of registered overvoltages (results of weekly measurements)

Registered overvoltages	Time	No of figure	Note
……	…… (hh.mm.ss – hh.mm.ss, pp.kk.aa)	……	……

TEST 3: Inertia

Scope of the test:

Inertia test.
A test that reasonably confirms the inertia constant of the turbine-generator, governor droop and other model parameters

Test conditions:

The machine is loaded to a small amount of MW (around xx MW to prevent the interference from protection relay operation) and Mvar value (under-excited condition preferred).
The AVR is set in auto control mode and the governor in speed droop control mode.
The unit circuit breaker input signal to the turbine controller is blocked to defeat the machine speed pre-set.

Success criteria(s):

Inertia constant/moment of inertia is verified.

Recorded signals:

- Actual generator voltage (U_{gen})
- Actual turbine speed
- Actual control valve position

Test Results

Calculated moment of inertia (based on test results):

$$J = \frac{P_r * \Delta T_0}{4\pi^2 {n_0}^2}$$

$P_r =$ W (reverse power)

$T_0 = 101{,}69\ s$ (reading from diagram [J t1-J t0])

$n_{0t} = \frac{10680}{60} Hz$

$n_{0g} = \frac{1500}{60} Hz$

$$J = \frac{* 101{,}69}{4 * \pi^2 * {n_0}^2}$$

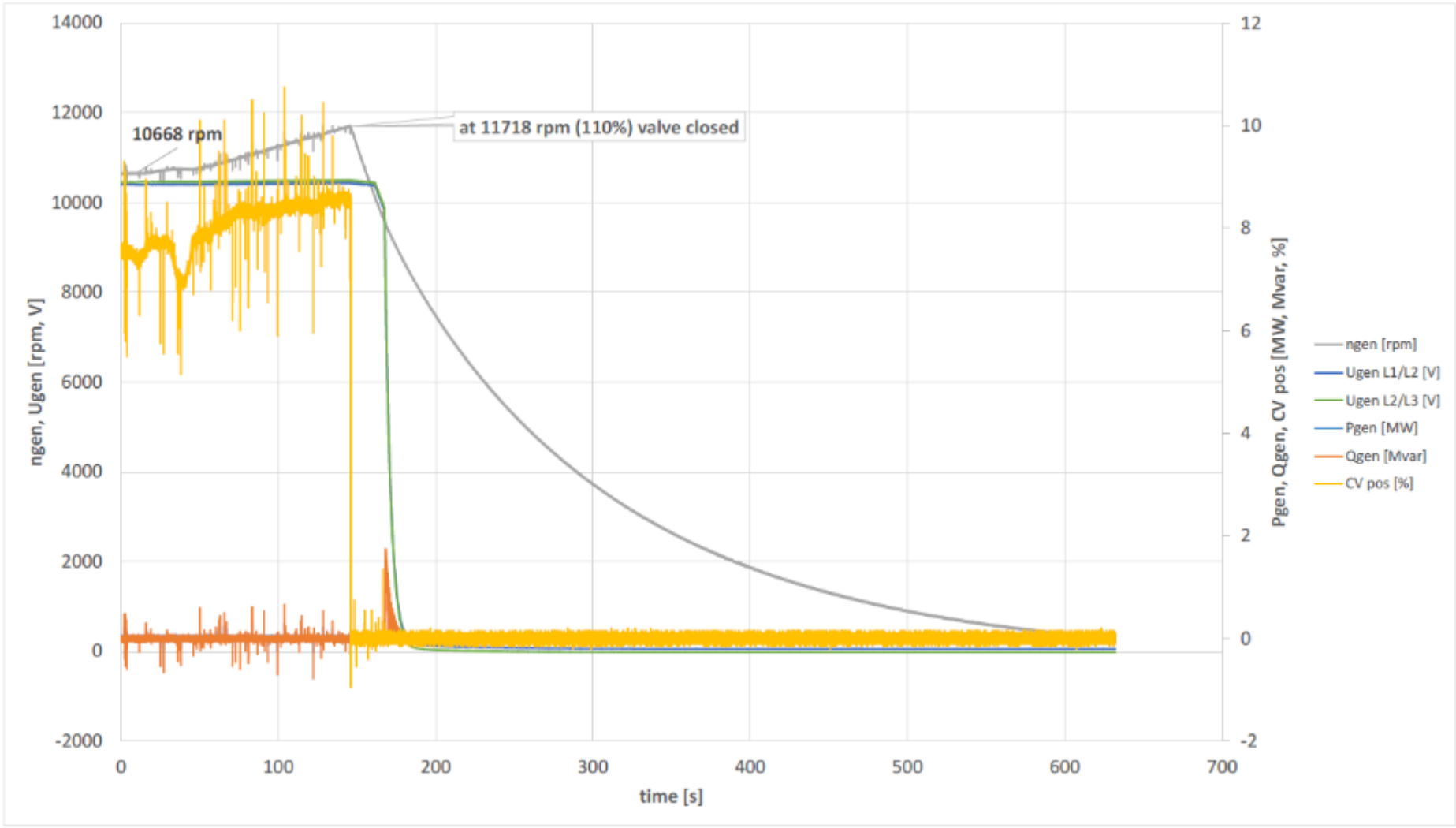
$J =$ kgm^2 based on 10680 rpm

$J =$ kgm^2 based on 1500 rpm

Calculated moment of inertia (based on 1500 rpm):

Turbosatz Trägheitsmoment turbo set *moment of inertia*	J [kg m²] =	

Deviation: < 1,5%


14000
12000
10000
8000
6000
4000
2000
0
-2000
ngen, Ugen [rpm, V]
12
10
8
6
4
2
0
-2
Pgen, Qgen, CV pos [MW, Mvar, %]
0
100
200
300
400
500
600
700
time [s]
10668 rpm
at 11718 rpm (110%) valve closed
ngen [rpm]
Ugen L1/L2 [V]
Ugen L2/L3 [V]
Pgen [MW]
Qgen [Mvar]
CV pos [%]

TEST 4: Generator AVR testing

1. Step change to AVR voltage reference with the generating unit on open circuit AND Manual variation of generating unit open circuit voltage

Scope of the test:

This test corresponds to standard tests C1A, C1B (Open Circuit AVR step).

Test conditions:

Generator circuit breaker in open position. Generator at nominal speed and voltage.

Step change to AVR voltage reference was generated internally in the AVR system. No

external connection via I/O unit.

Success criteria(s):

1. Automatic voltage regulation is operating correctly;

2. The voltage shall be increased and decreased steeply causing the change of the generator output voltage from 95% to 105% and from 105% to 95% of the rated voltage, the generator output voltage shall comply with the following requirement: if voltage is increased to 90% within the abovementioned range, the time of voltage increase in case of brushless exciter 0.2–0.5 seconds;

3. If voltage is decreased in the range from 90% to 0%, the time for voltage decrease shall be 0.2–0.8 seconds in case of brushless exciter. The generator voltage must be non-oscillating;

4. The voltage overshoot shall be < 15%;

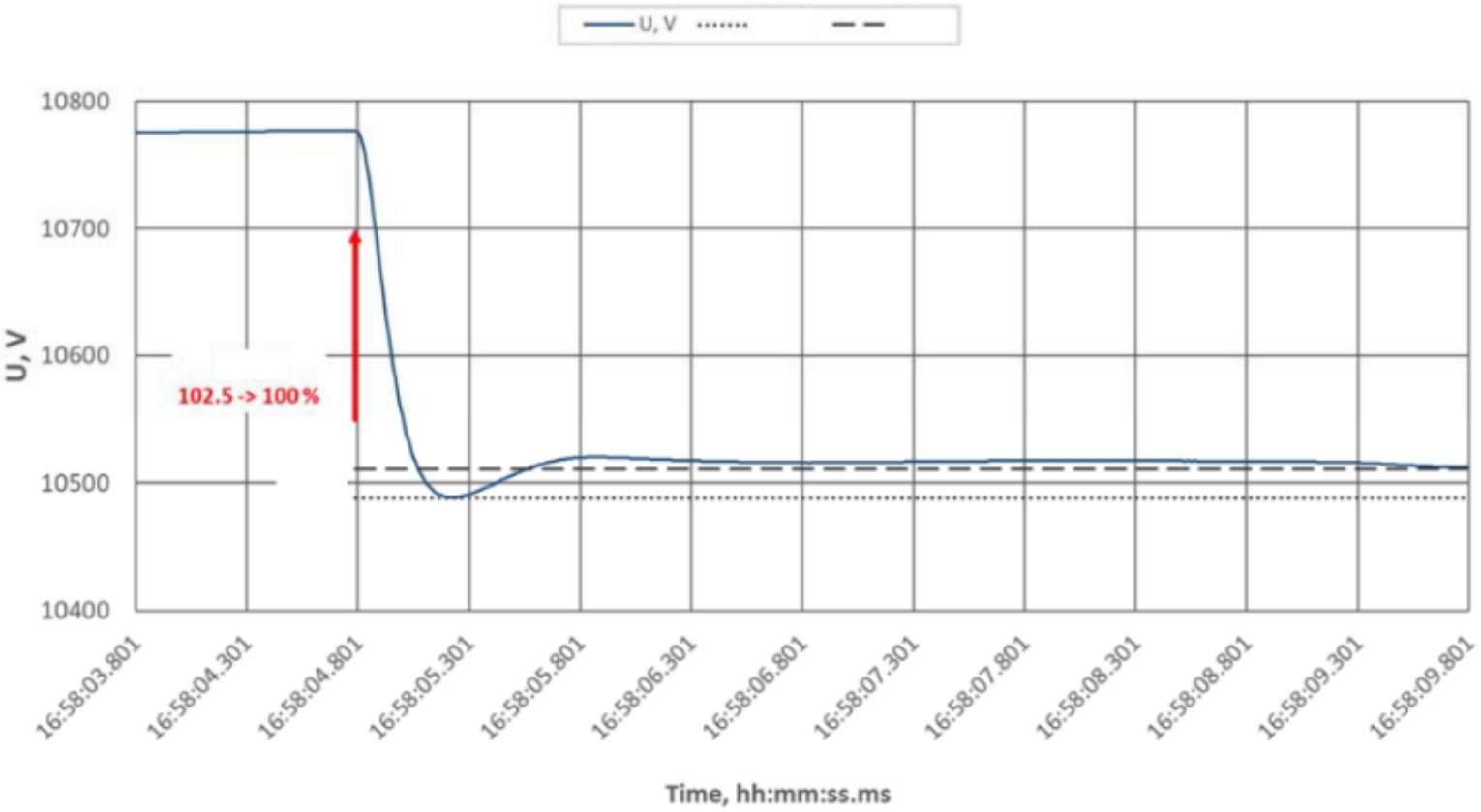
5. The ceiling voltage is > 1.6 times the rated excitation voltage. “Excitation system ceiling voltage” means the maximum DC voltage, which the excitation system is able to provide from its terminals under the defined conditions.

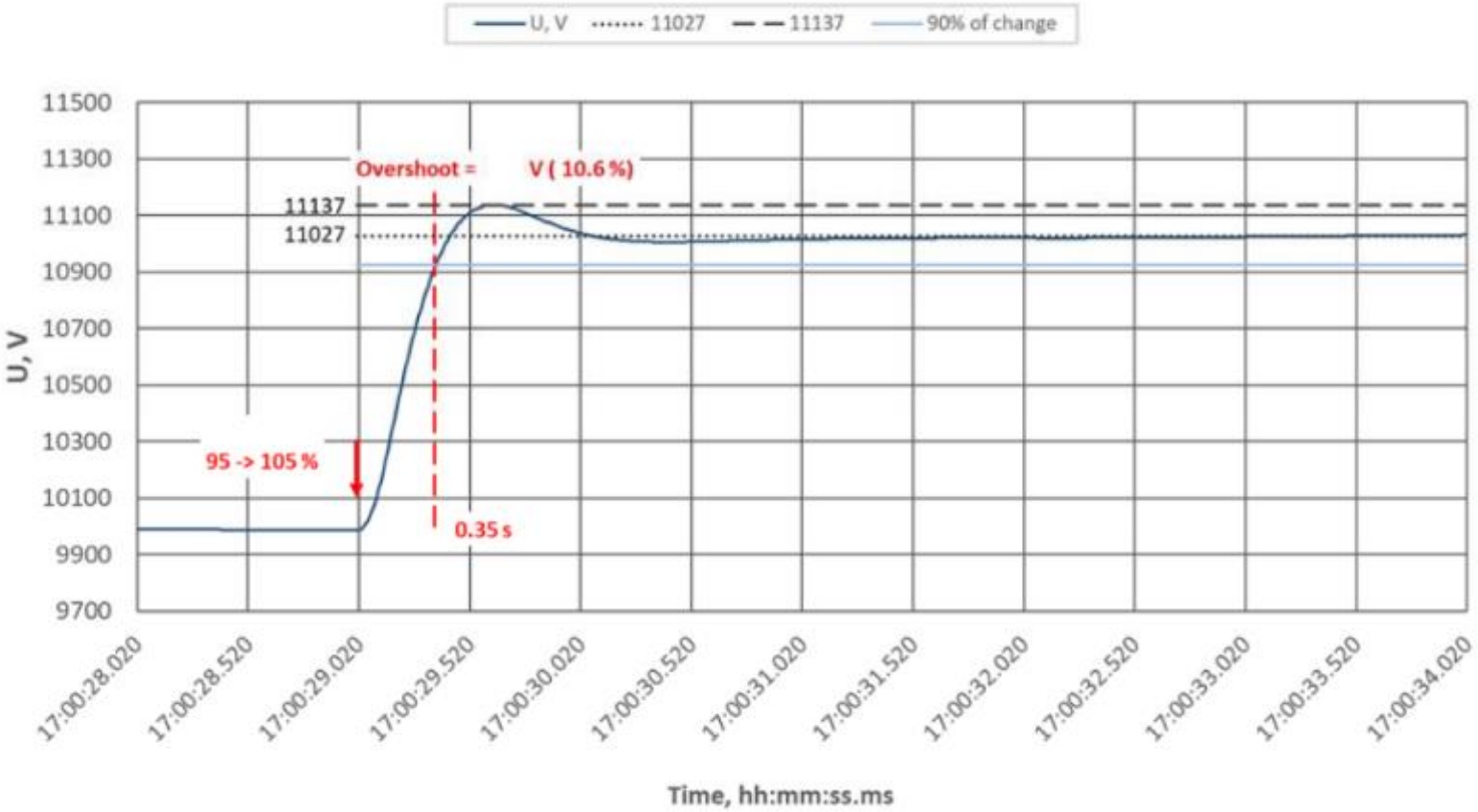
Recorded signals:

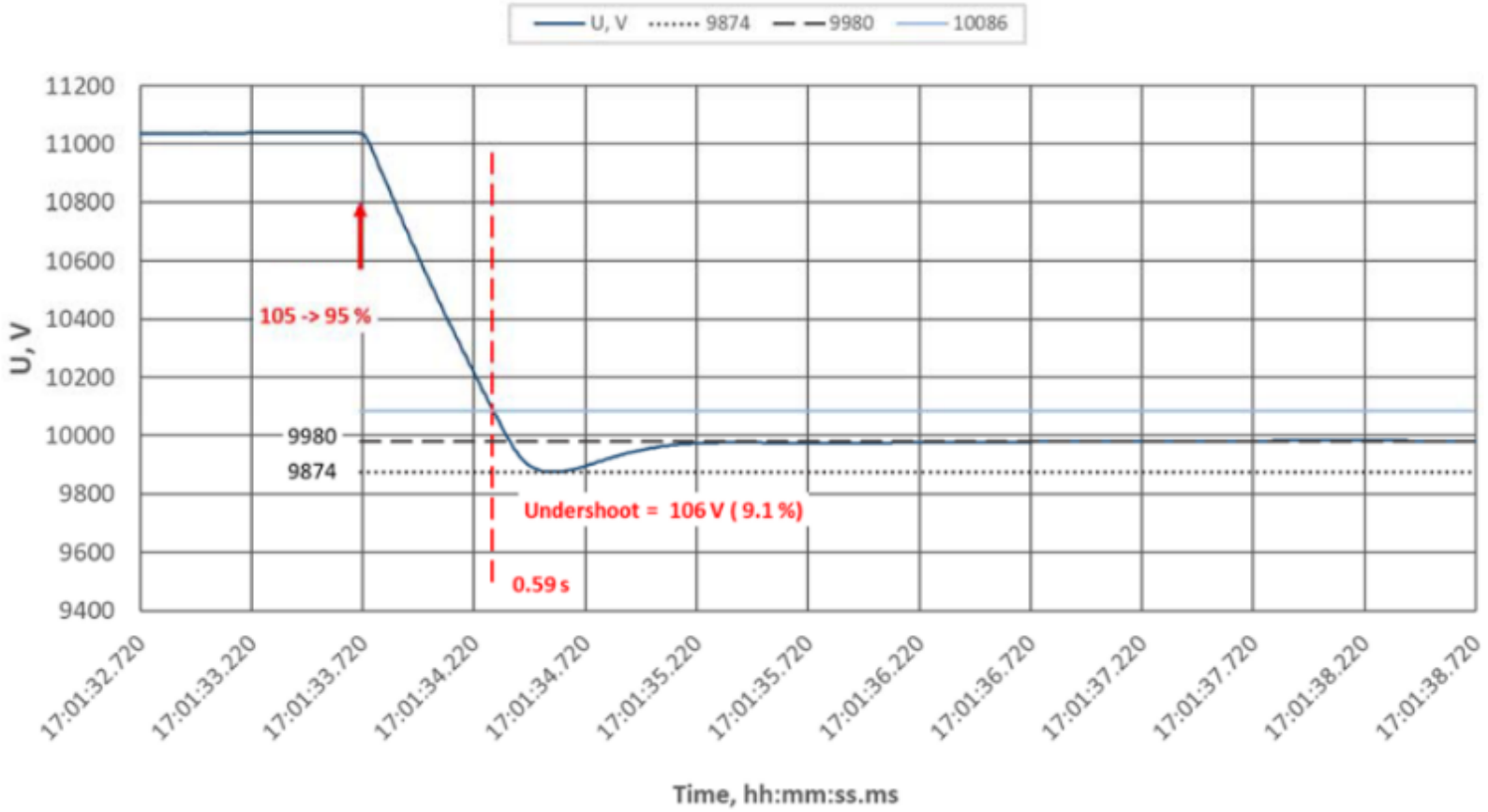
Vgen, Iexf, Vexf, Vref, ΔVref at sampling rate 10 ms;

ngen at sampling rate 1 s.

Test Results




U, V
11027
11137
90% of change
11500
11300
11100
10900
10700
10500
10300
10100
9900
9700
U, V
Overshoot =
V (10.6 %)
11137
11027
95 -> 105 %
0.35 s
17:00:28.020
17:00:28.520
17:00:29.020
17:00:29.520
17:00:30.020
17:00:30.520
17:00:31.020
17:00:31.520
17:00:32.020
17:00:32.520
17:00:33.020
17:00:33.520
17:00:34.020
Time, hh:mm:ss.ms



2. Manual variation of generating unit open circuit voltage

Scope of the test:

To verify excitation system action.

Test conditions:

Generator circuit breaker in open position. Generator at nominal speed and voltage. Step change to AVR voltage reference was generated internally in the AVR system. No external connection via I/O unit.

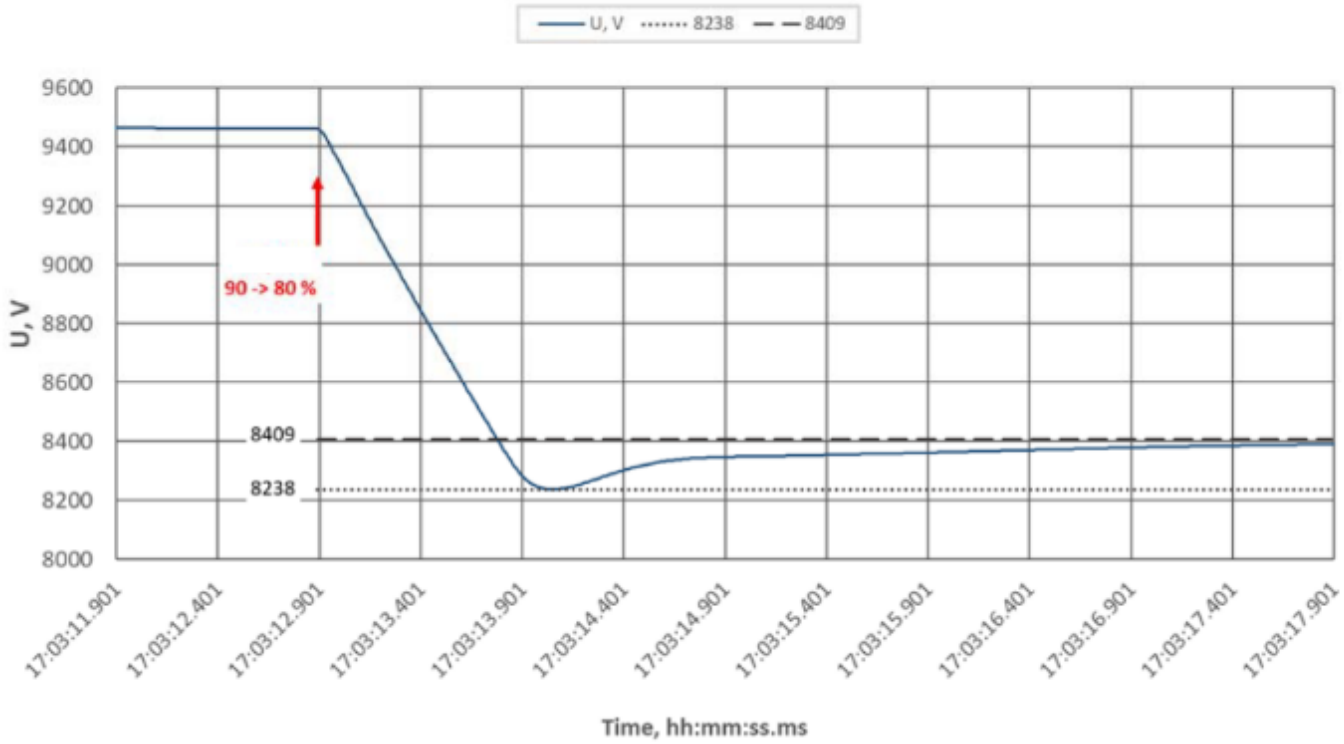
Success criteria(s):

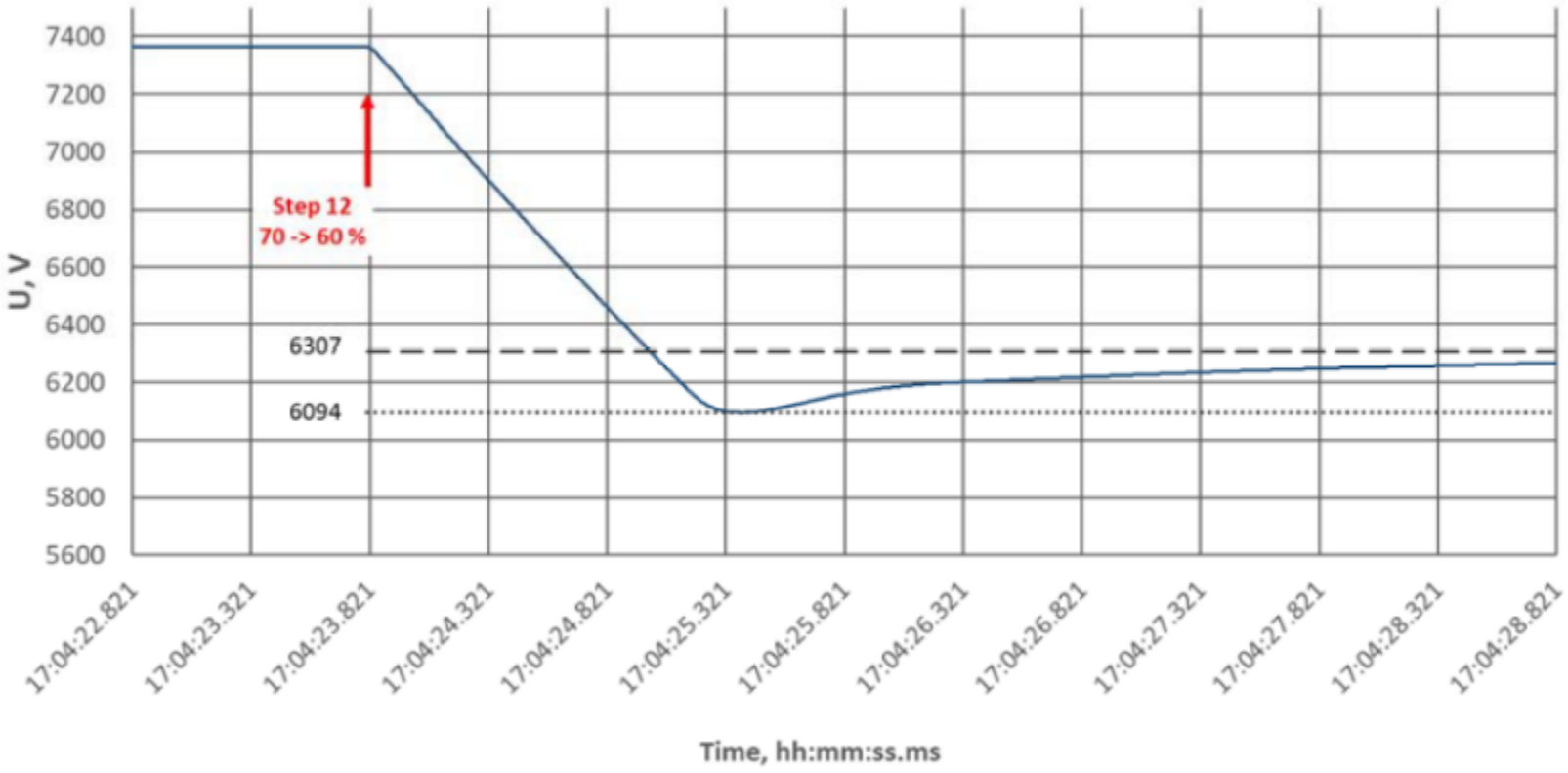
Stator terminal voltage is changing according to input and voltage is not occillating.

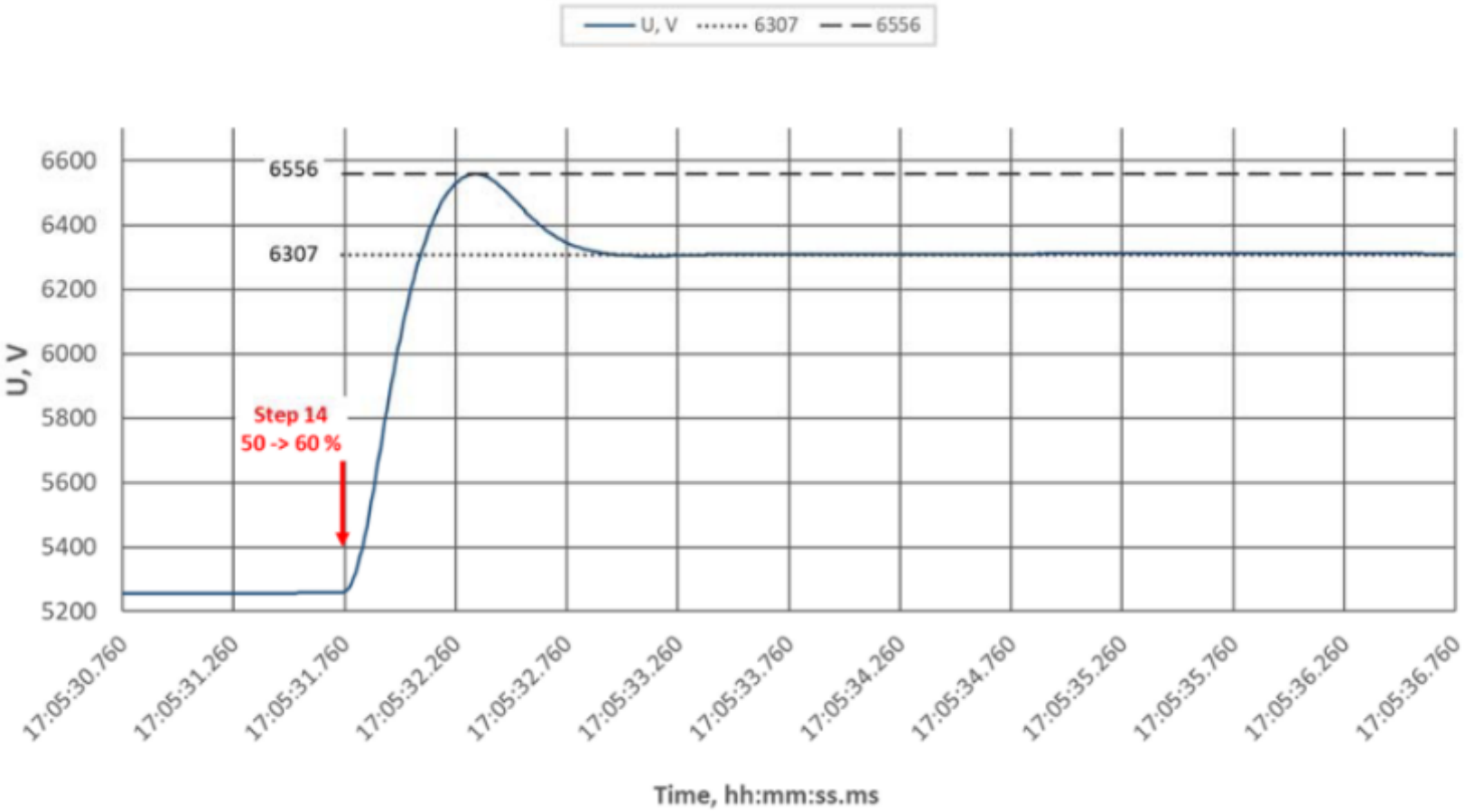
Recorded signals:

V_{gen}, I_{exf}, V_{exf}, V_{ref}, ΔV_{ref} at sampling rate 10 ms;
n_{gen} at sampling rate 1 s.

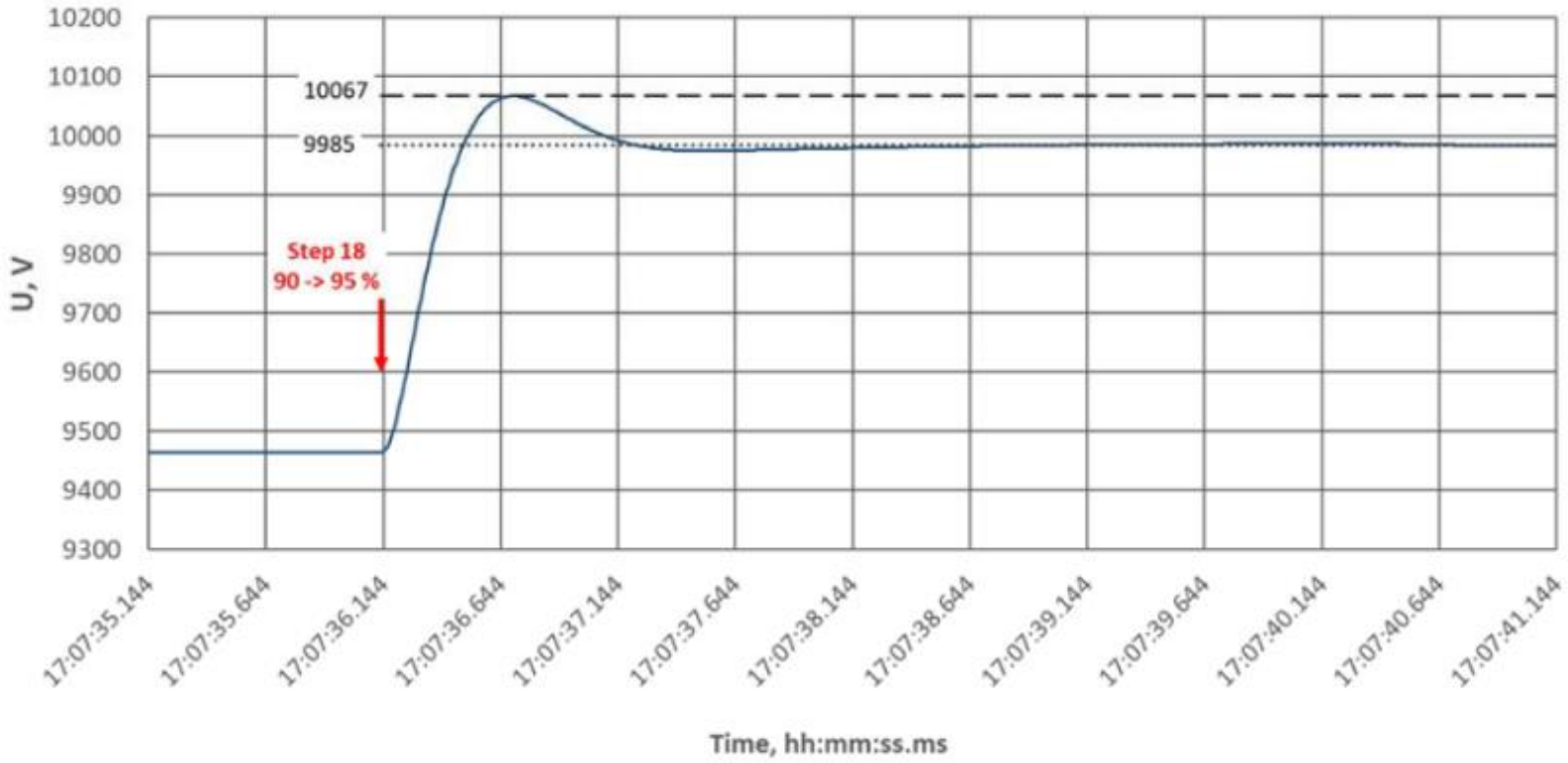
Test Results

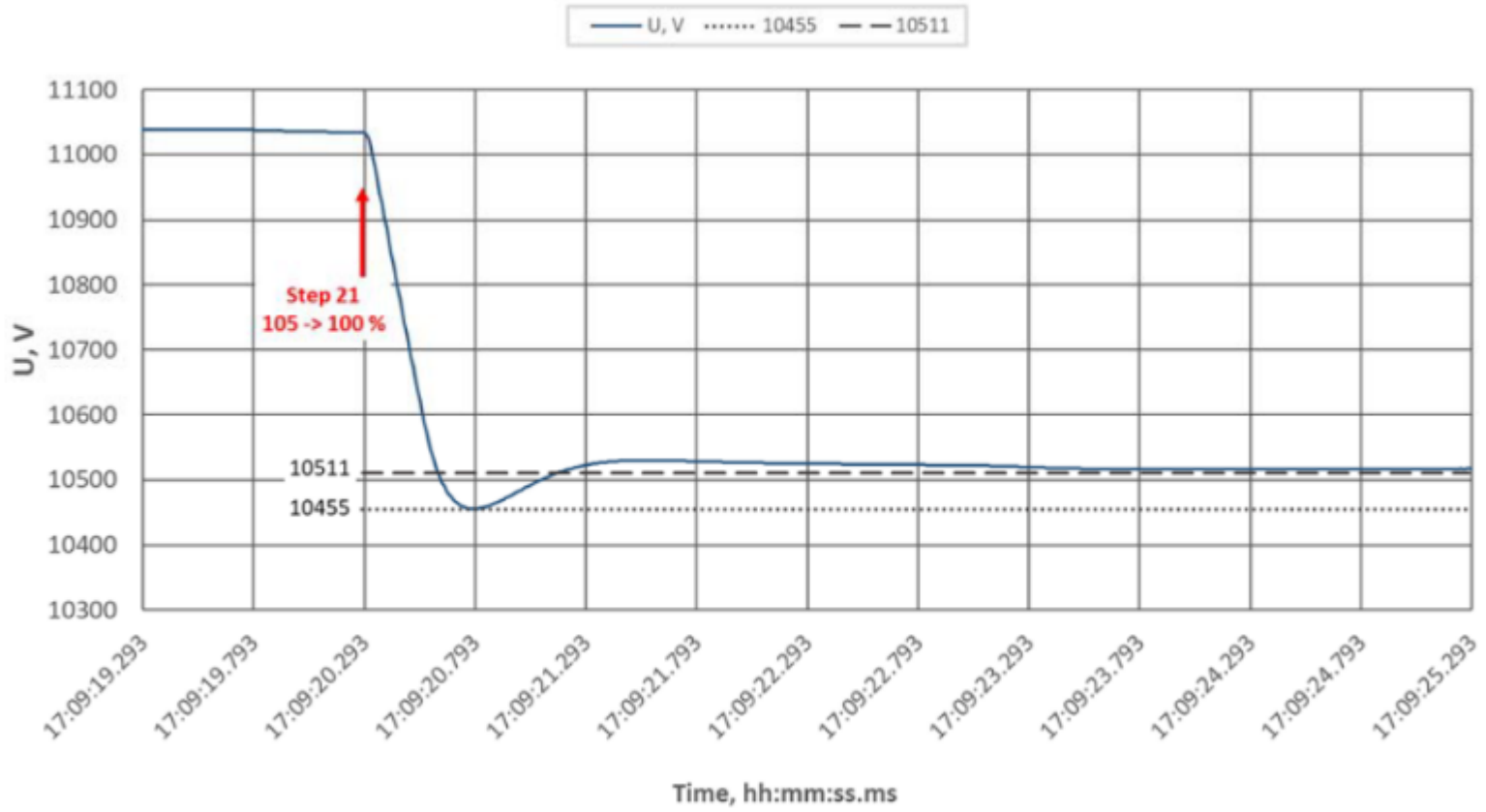

U, V
8238
8409
9600
9400
9200
9000
8800
8600
8400
8200
8000
U, V
90 -> 80 %
8409
8238
17:03:11.901
17:03:12.401
17:03:12.901
17:03:13.401
17:03:13.901
17:03:14.401
17:03:14.901
17:03:15.401
17:03:15.901
17:03:16.401
17:03:16.901
17:03:17.401
17:03:17.901
Time, hh:mm:ss.ms


7400
7200
7000
6800
6600
6400
6200
6000
5800
5600
U, V
Step 12
70 -> 60 %
6307
6094
17:04:22.821
17:04:23.321
17:04:23.821
17:04:24.321
17:04:24.821
17:04:25.321
17:04:25.821
17:04:26.321
17:04:26.821
17:04:27.321
17:04:27.821
17:04:28.321
17:04:28.821
Time, hh:mm:ss.ms


U, V
6307
6556
6600
6400
6200
6000
5800
5600
5400
5200
U, V
6556
6307
Step 14
50 -> 60 %
17:05:30.760
17:05:31.260
17:05:31.760
17:05:32.260
17:05:32.760
17:05:33.260
17:05:33.760
17:05:34.260
17:05:34.760
17:05:35.260
17:05:35.760
17:05:36.260
17:05:36.760
Time, hh:mm:ss.ms


U, V
8409
8622
8700
8500
8300
8100
7900
7700
7500
7300
U, V
8622
8409
Step 16
70 -> 80 %
17:06:37.561
17:06:38.061
17:06:38.561
17:06:39.061
17:06:39.561
17:06:40.061
17:06:40.561
17:06:41.061
17:06:41.561
17:06:42.061
17:06:42.561
17:06:43.061
17:06:43.561
Time, hh:mm:ss.ms


10200
10100
10000
9900
9800
9700
9600
9500
9400
9300
U, V
10067
9985
Step 18
90 -> 95 %
17:07:35.144
17:07:35.644
17:07:36.144
17:07:36.644
17:07:37.144
17:07:37.644
17:07:38.144
17:07:38.644
17:07:39.144
17:07:39.644
17:07:40.144
17:07:40.644
17:07:41.144
Time, hh:mm:ss.ms



3. Steady state over-excitation limiter (OEL) operation

Scope of the test:

To verify OEL operation.

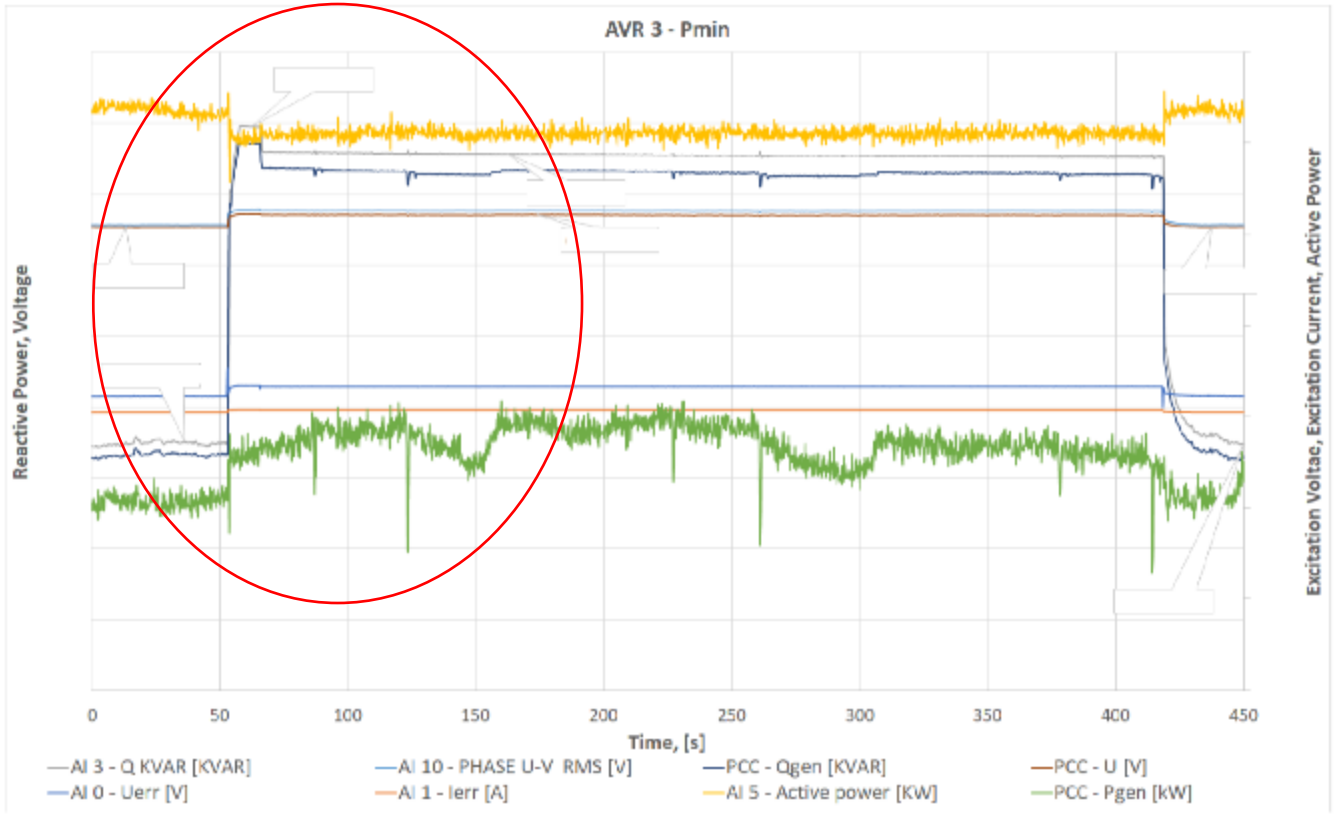
Test conditions:

Success criteria(s):

OEL limits reactive power and keeps generator in stable operation mode.

Recorded signals:

Test Results



This kind of figure for every active power level to be added. (Most important part is in red circle. Clearly to be presented OEL action.)

Second example is shown below.

Test conditions:

- Turbine synchronised
- Field exciter in automatic mode

Test execution:

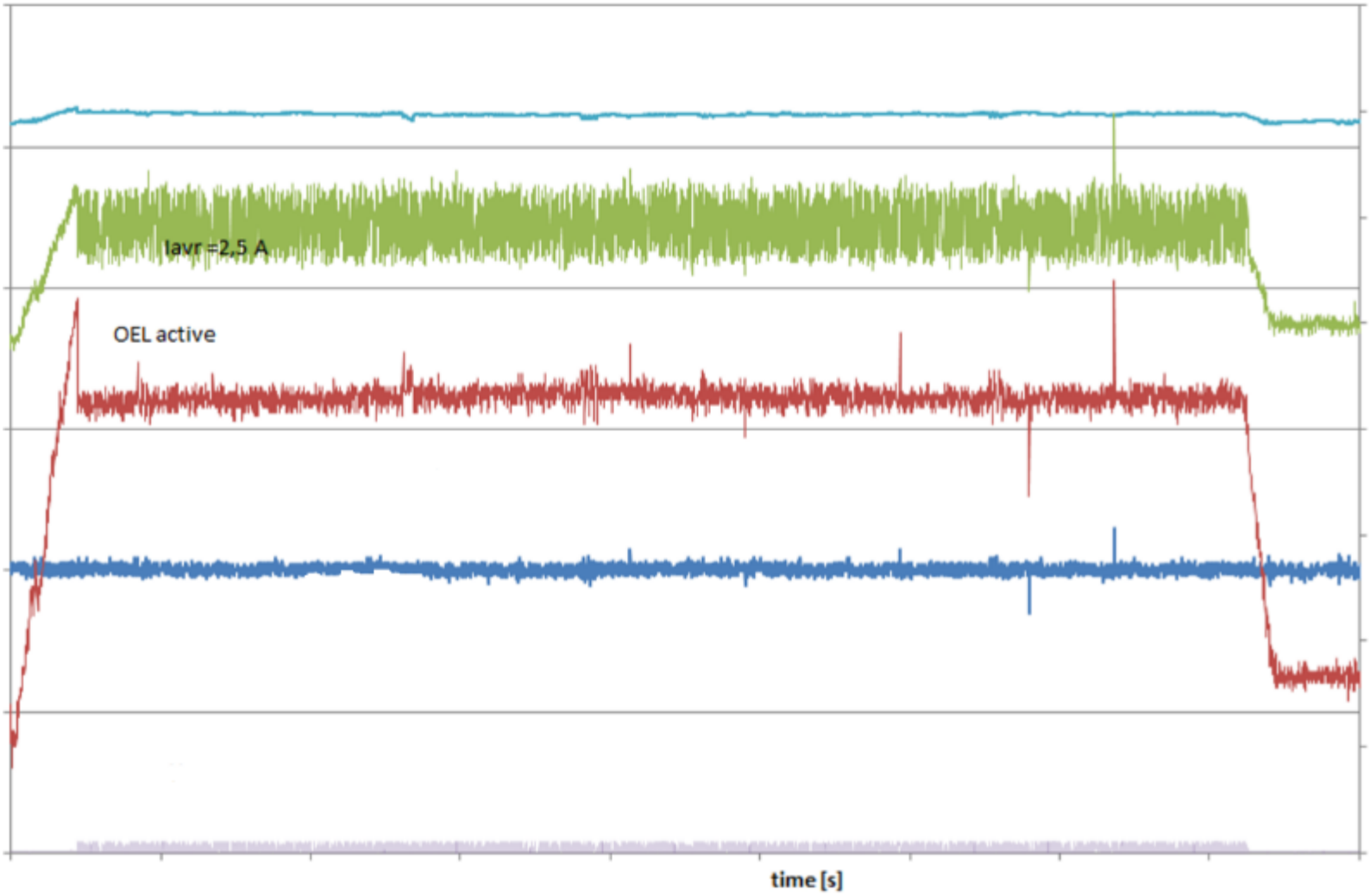
- nominal stator terminal voltage
- power output
    - XX MW
    - XX MW
    - XX MW
    - XX MW
    - XX MW
- excitation automatic control
- maximum overexcitation / reduced OEL value

General content:

- Actual Power (Pgen)
- Actual reactive power (Qgen)
- Actual generator voltage (Ugen)
- Actual field current (IAVR)
- Actual field voltage (Uavr)

Measured values:

Test results:



Record: Turbine output XX

4. Steady state under-excitation limiter (UEL) operation

Scope of the test:

To verify UEL operation.

Test conditions:

MVAr outputs at UEL setting slow raising of excitation to just bring UEL into operation and waiting stabilization of the output signal (5 minutes per test).
With reduced UEL values

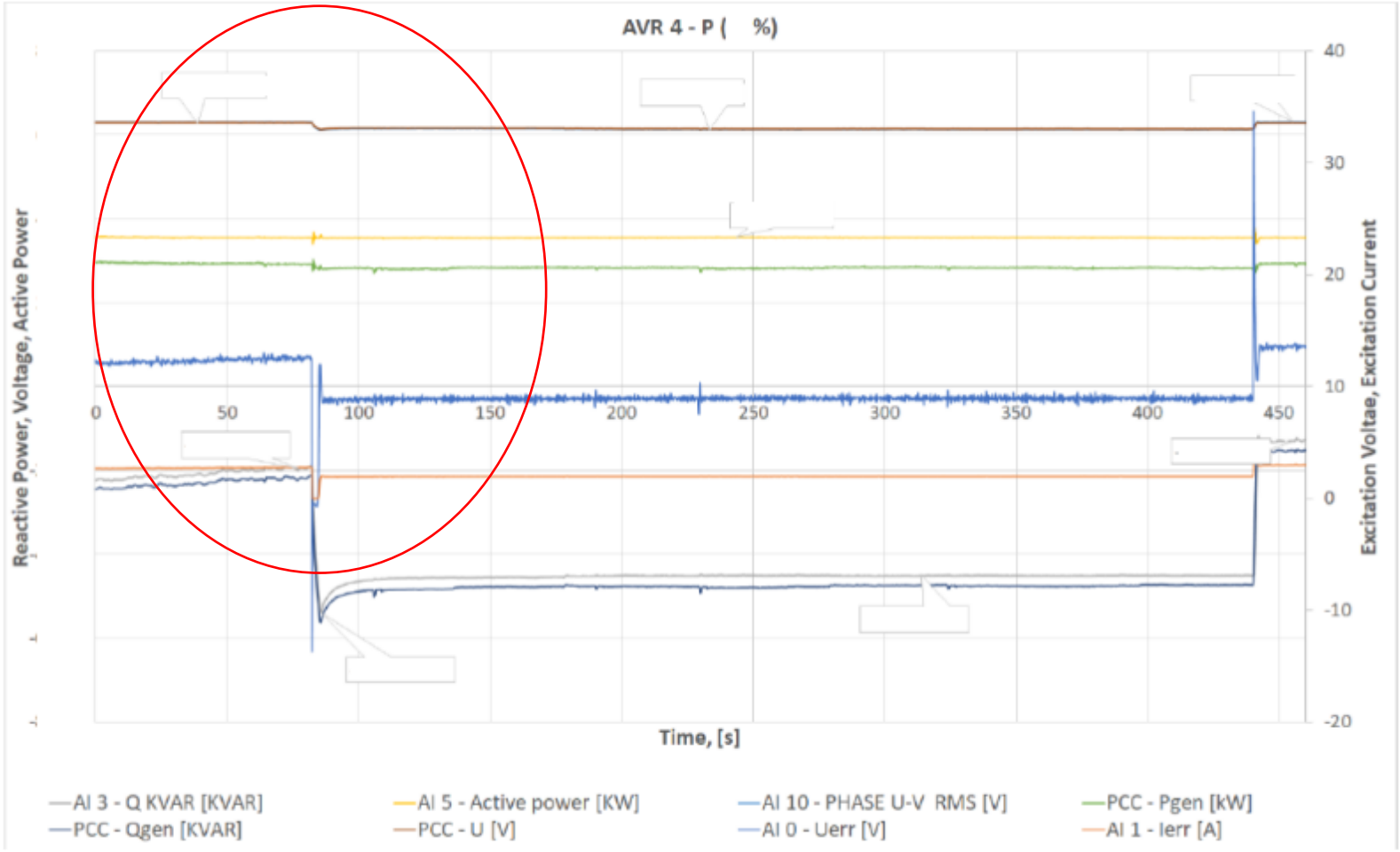
Turbine synchronised
Field exciter in automatic mode
(a) Pn 100% / X MW
(b) Pn 75% / X MW
(c) Pn 50 % / X MW
(d) Pn 25% / X MW
(e) Pn MIN / X MW

Success criteria(s):

OEL limits reactive power and keeps generator in stable operation mode.

Recorded signals:

Test Results



This kind of figure for every active power level to be added. (Most important part is in red circle. Clearly to be presented UEL action.)

5. Step change to AVR voltage reference with the generating unit connected to the system (PSS out of service). Generating unit output levels: (i)50% rated MW, and (ii)100% rated MW

Scope of the test:

Test conditions:

• nominal stator terminal voltage

• unity power factor or under exited operation

• system base load OR typical conditions at the local equipment and typical electrical connection to the transmission or distribution system

(a) +1 %

(b) -1 %

(c) +2,5 %

(d) -2,5 %

(e) +5 %

(f) -5 %

(i) 3,555 MW

(ii)7,100 MW

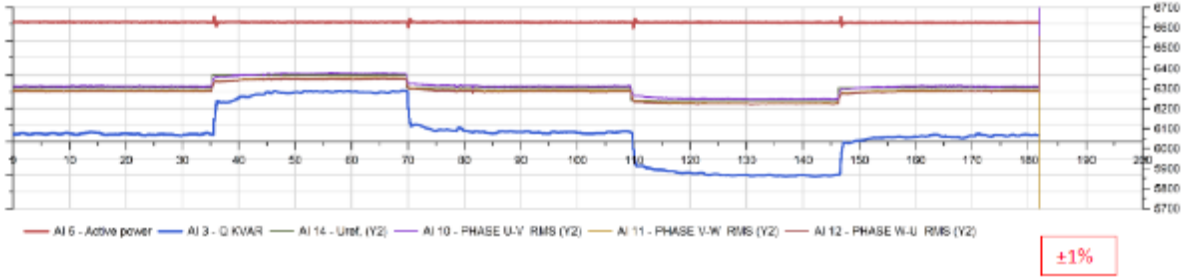
Success criteria(s):

No oscillations are detected in the voltage or active power

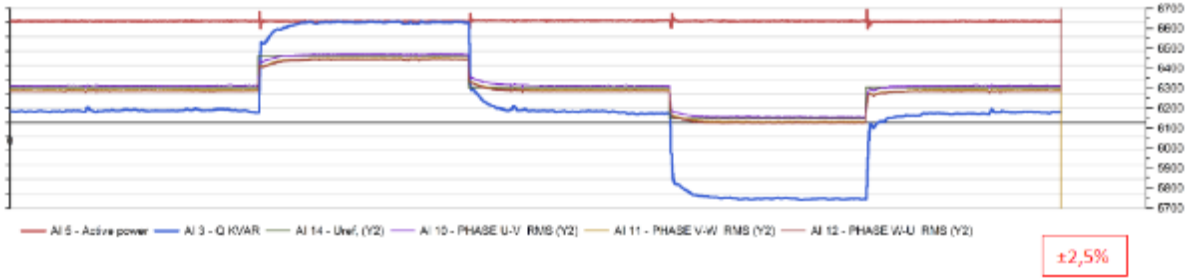
Recorded signals:

Test Results

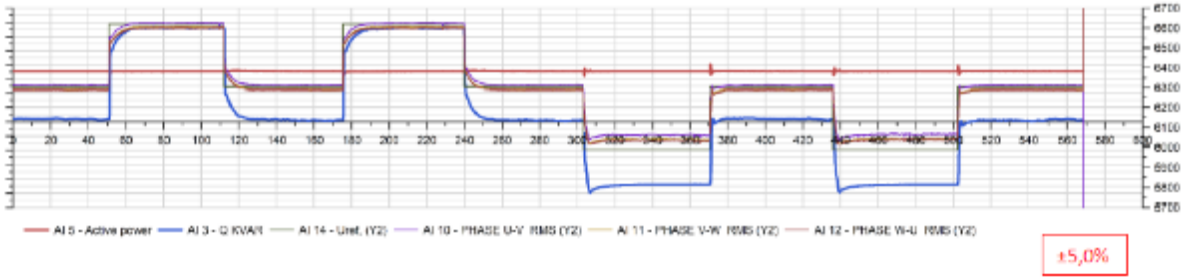
1.1.1. Records at 50% Pn



±1%

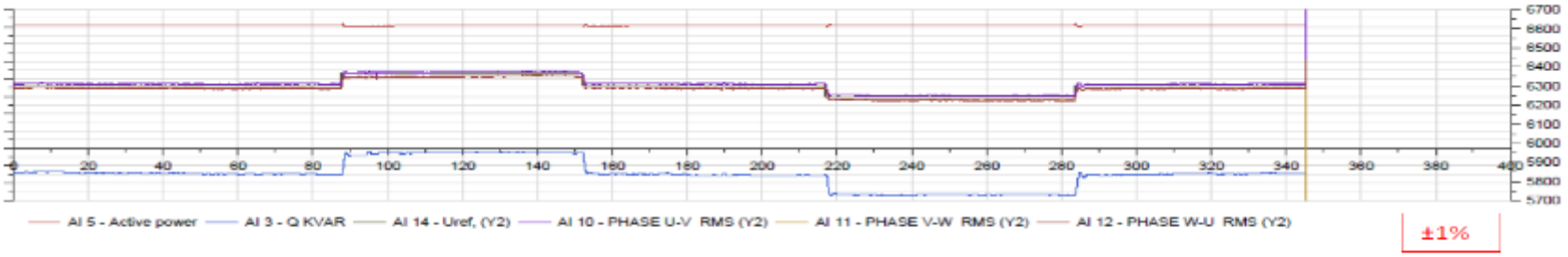


±2,5%

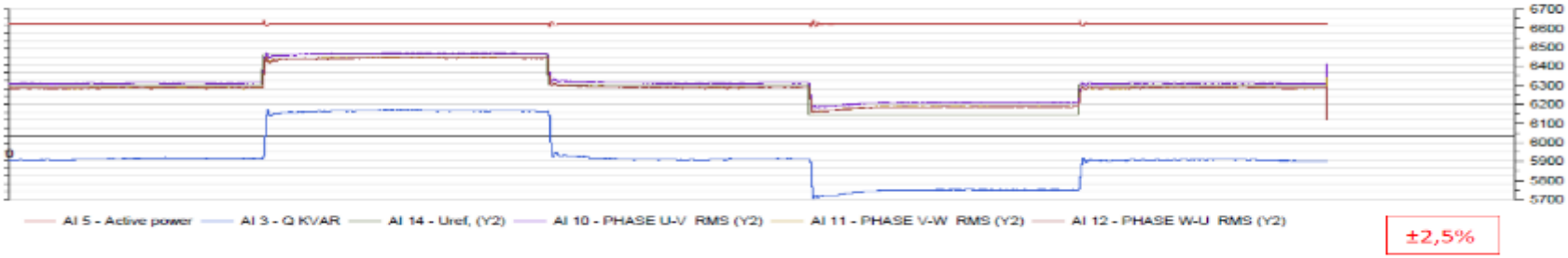


±5,0%

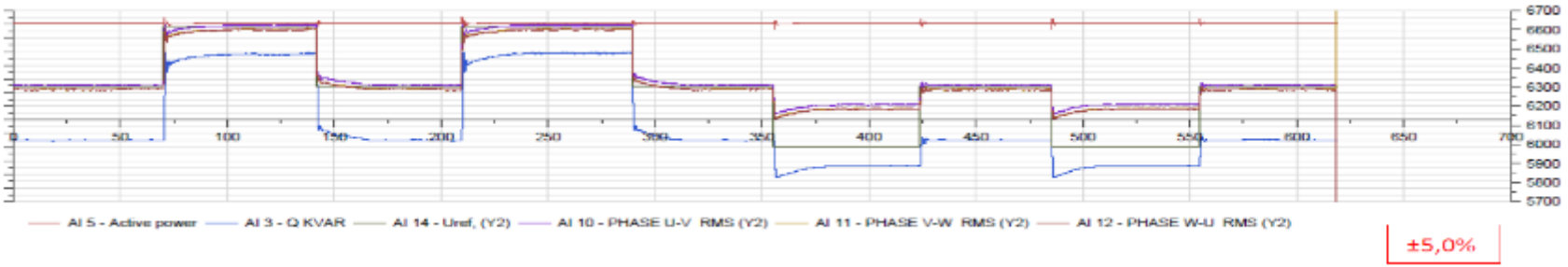
1.1.2. Records at 100% Pn



±1%



±2,5%



±5,0%

Second example :

Test conditions:

- Generator connected to line
- Field exciter in automatic mode

- Power system Stabiliser out of service

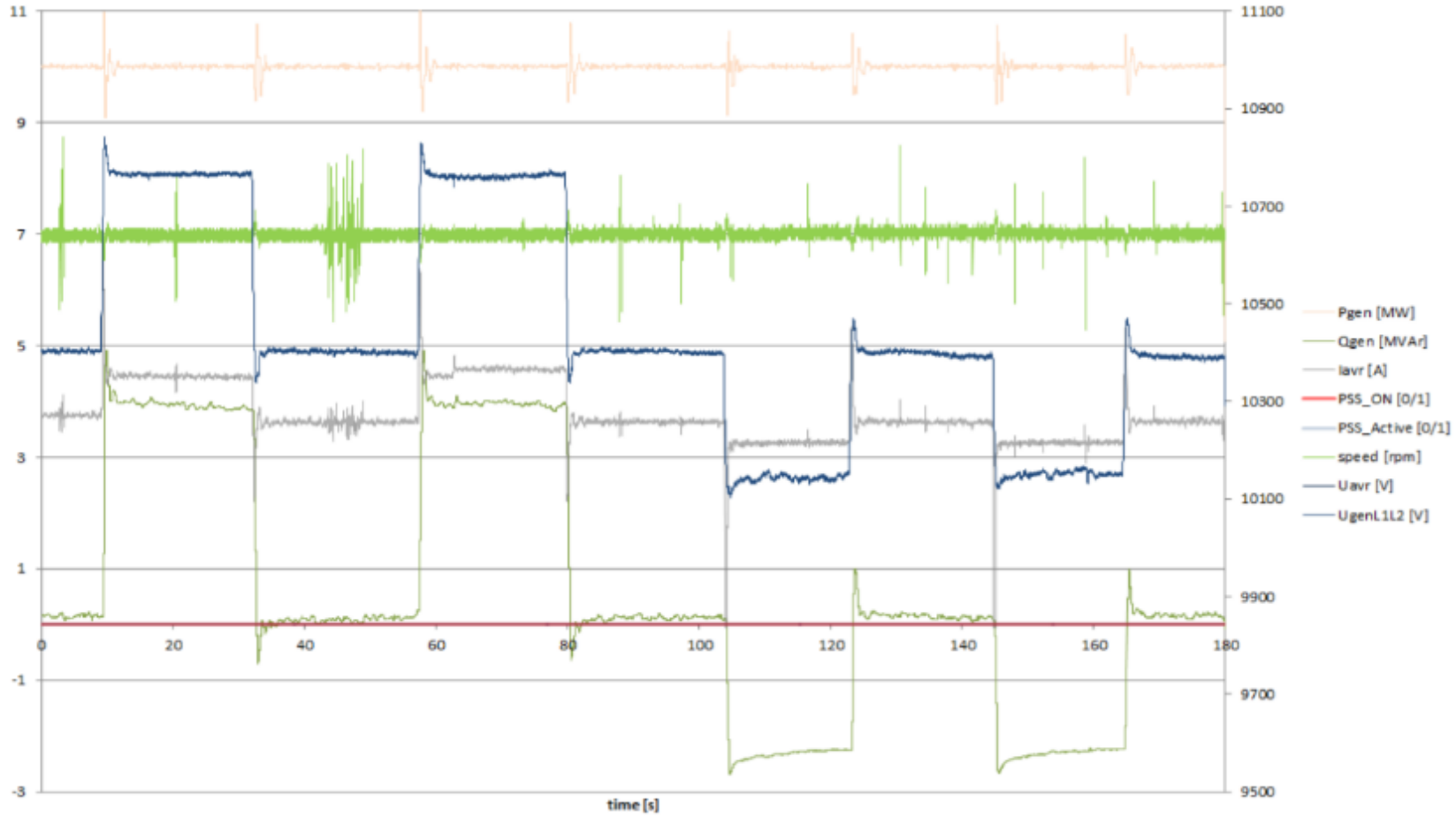
Test execution:

- Change Setpoint according test description
- nominal stator terminal voltage
- unity power factor or under exited operation
- system base load OR typical conditions at the local equipment and typical electrical connection to the transmission or distribution system
- (a) +1 %
- (b) -1 %
- (c) +2,5 %
- (d) -2,5 %
- (e) +5 %
- (e) -5 %
- (i) X MW
- (ii) X MW

General content:

- Actual generator voltage (Ugen)
- Actual reactive power (Qgen)
- Actual power (Pgen)
- Actual field current (IAVR)
- Actual turbine speed
- Sampling rate 10 ms

Test results:



Full record (ii)(e) and (ii)(f) - +/- 5 % set-point change

Same approach to all the different active power set points.

6. As for 6 but with the PSS in service

Scope of the test:

Test conditions:

Success criteria(s):

Recorded signals:

Test Results

Test conditions:

- Generator connected to line
- Field exciter in automatic mode
- Power system Stabiliser in service

Test execution:

- Change set-point according test description
- Care must be taken not to excite large or prolonged oscillations in MW etc. Therefore, smaller step changes must always precede larger step changes to avoid such oscillations
- nominal stator terminal voltage
- unity power factor or under exited operation
- system base load OR typical conditions at the local equipment and typical electrical connection to the transmission or distribution system
- (a) +1 %
- (b) -1 %
- (c) +2,5 %
- (d) -2,5 %
- (e) +5 %
- (e) -5 %
- (i) X MW
- (ii) X MW

General content:

- Actual generator voltage (Ugen)
- Actual reactive power (Qgen)
- Actual power (Pgen)
- Actual field current (IAVR)
- Actual field voltage (UAVR)
- Actual turbine speed
- PSS out
- Sampling rate 10 ms

Test results:

7. Step change to AVR voltage reference with the generating unit connected to the system. (PSS out of service)

Test conditions:

- Generator connected to line
- Field exciter in automatic mode
- Power system Stabiliser out of service

Test execution:

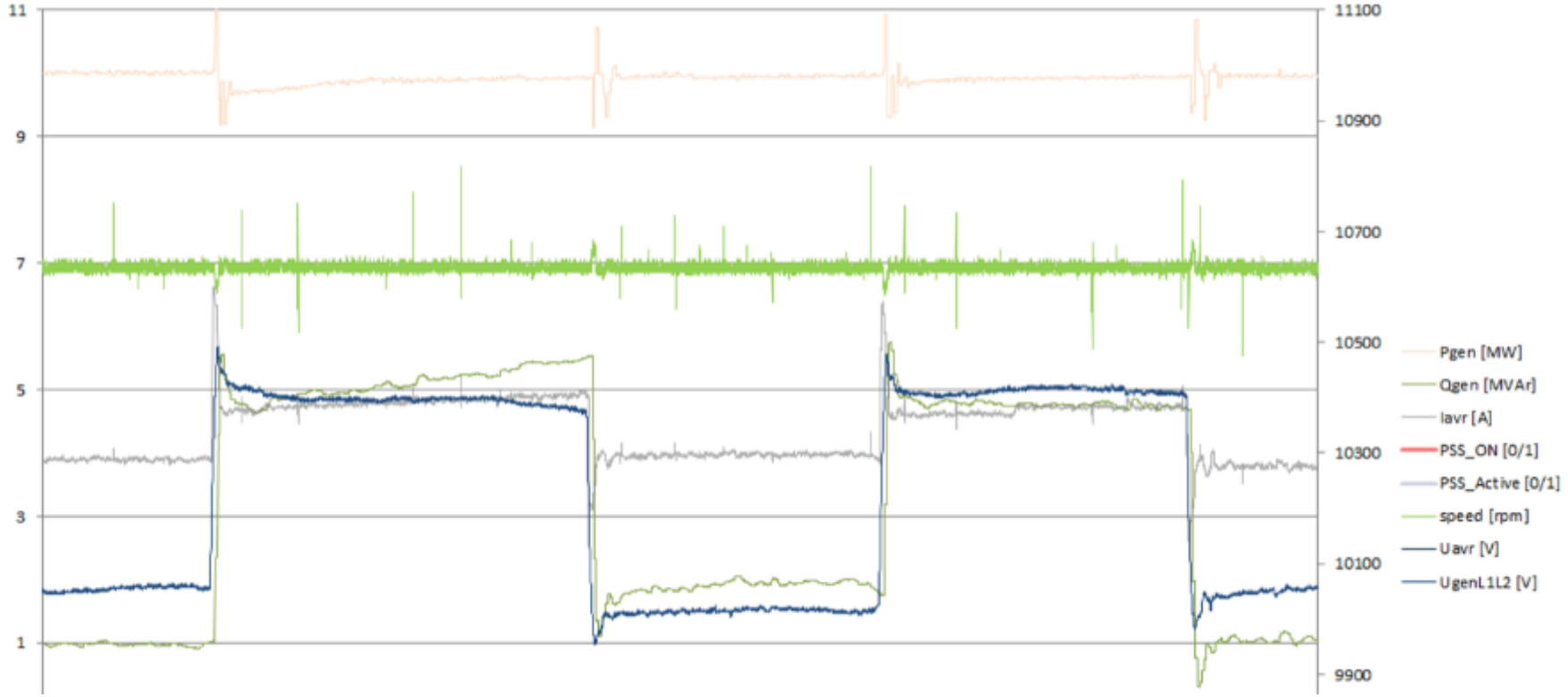
- Change set-point according test description
- nominal stator terminal voltage
- unity power factor or under exited operation
- system base load OR typical conditions at the local equipment and typical electrical connection to the transmission or distribution system
- generating unit output at XX MW
- (a) +5 %

- (b) -5 %
- (i) relatively weak connection to the transmission or distribution system
- (ii) relatively strong connection to the transmission or distribution system

General content:

- Actual generator voltage (Ugen)
- Actual reactive power (Qgen)
- Actual power (Pgen)
- Actual field current (IAVR)
- Actual field voltage (UAVR)
- Actual turbine speed
- PSS In
- PSS Out

Test results:



Record (i)(a)(b)(a)(b) ± 5 % set-point change

8. As for 7 but with the PSS in service

Scope of the test:

Test conditions:

• nominal stator terminal voltage

• unity power factor or under exited operation

• system base load OR typical conditions at the local equipment and typical electrical connection to the transmission or distribution system

(a) +1 %

(b) -1 %

(c) +2,5 %

(d) -2,5 %

(e) +5 %

(f) -5 %

(i) x MW

(ii)X MW

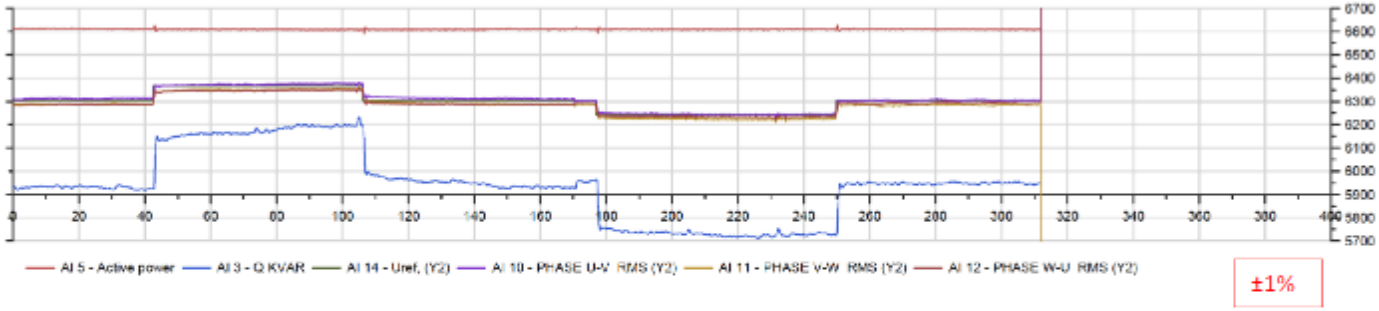
Success criteria(s):

No oscillations are detected in the voltage or active power

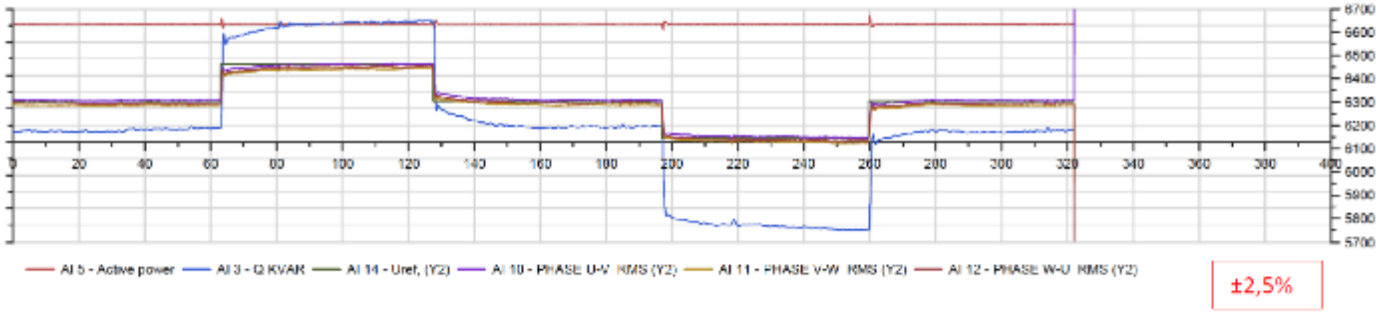
Recorded signals:

Test Results

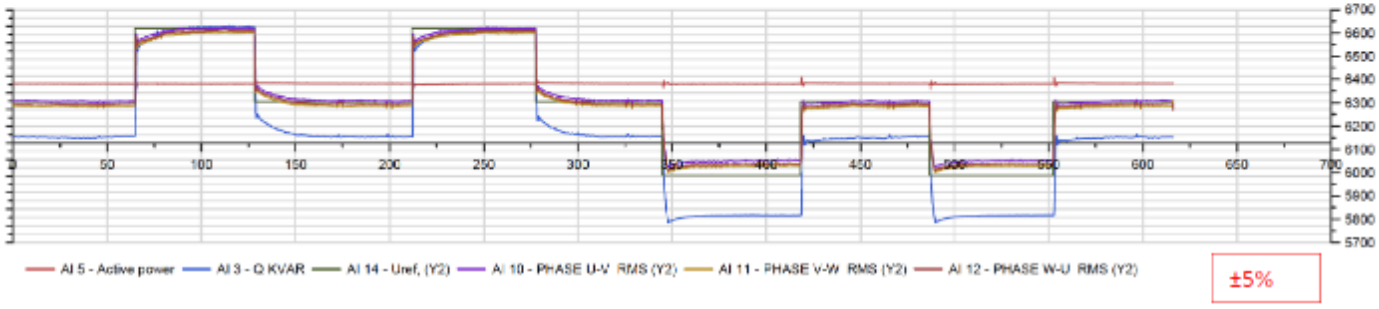
1.1.1 Records at 50% Pn



±1%

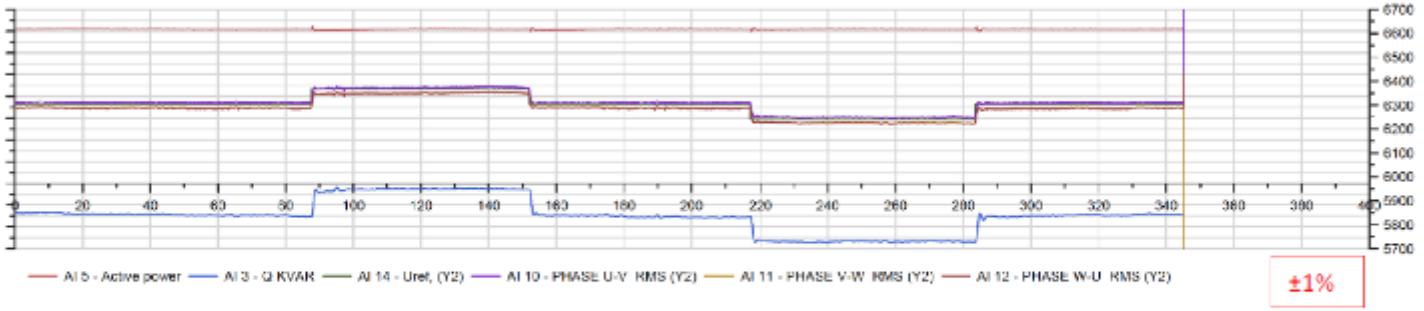


±2,5%

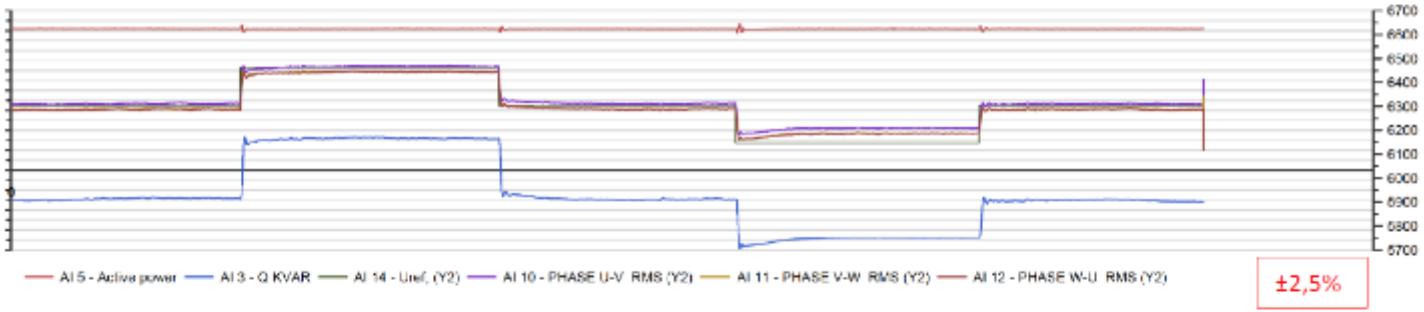


±5%

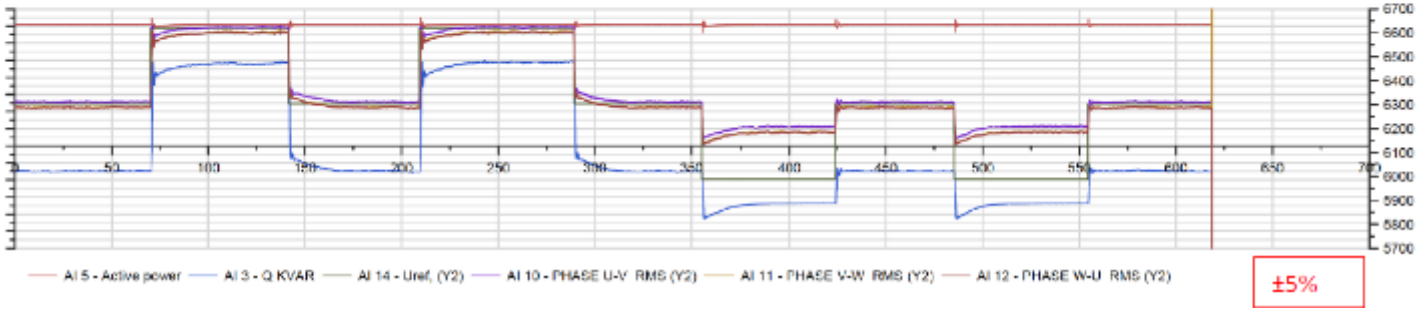
1.1.2 Records at 100% Pn



±1%



±2,5%



±5%

Comparison with PSS ON/PSS OFF must be shown for same steps changes as shown below.

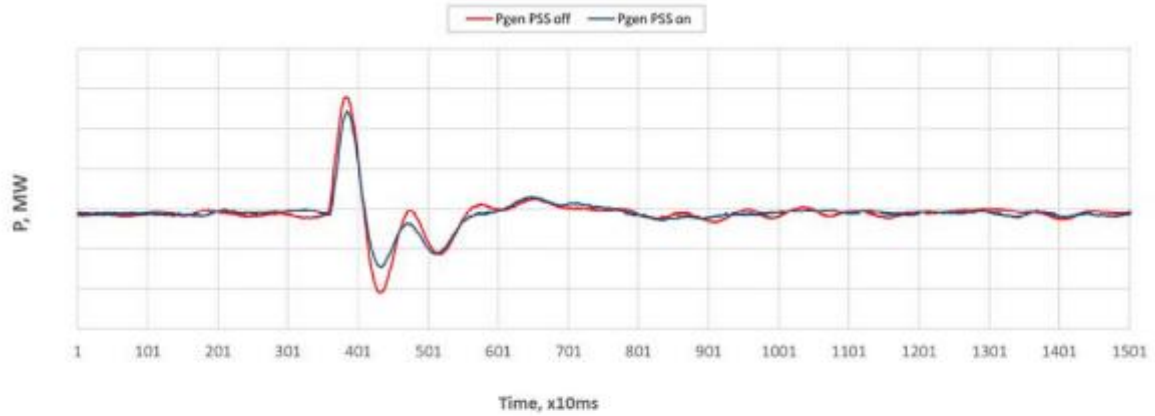


Figure 3.1. Active power measurements from generator terminals, step 9 and step 18 (Uref change -5%) setpoint Pgen = MW. PSS on/PSS off.

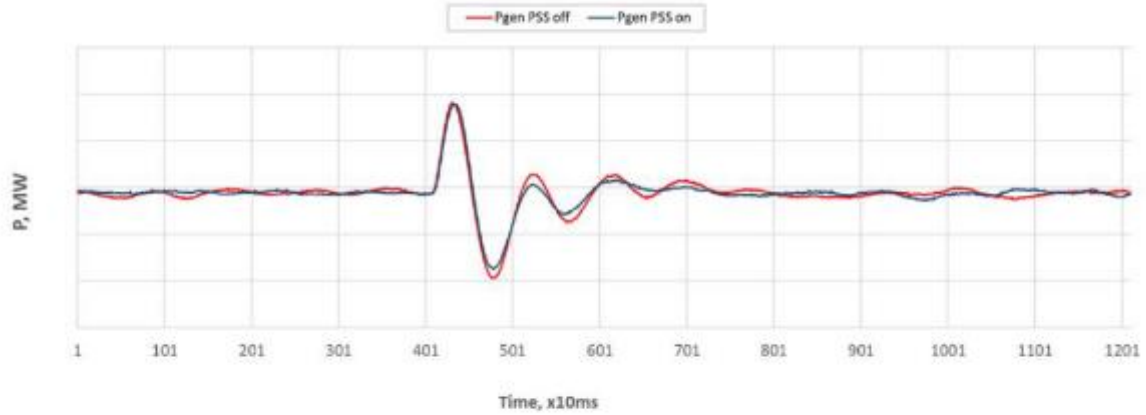


Figure 3.2. Active power measurements from generator terminals, step 10 and step 19 (Uref change +5%) setpoint Pgen = MW. PSS on/PSS off.

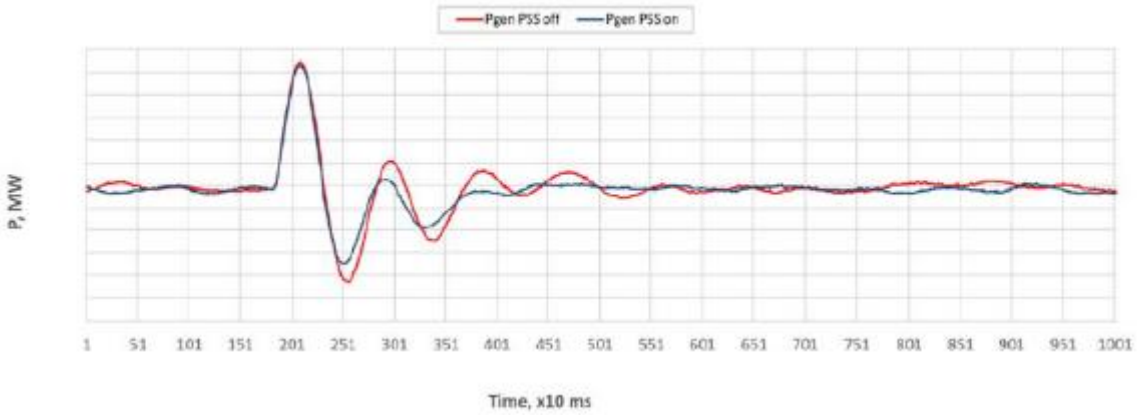


Figure 3.3. Active power measurements from generator terminals, step 28 and step 39 (Uref change -5%) setpoint Pgen = MW. PSS on/PSS off.

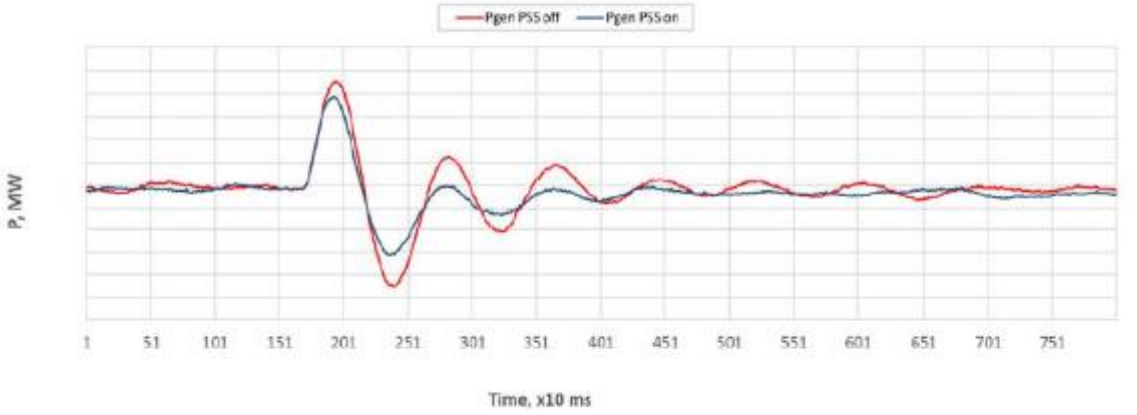


Figure 3.4. Active power measurements from generator terminals, step 29 and step 40 (Uref change +5%) setpoint Pgen = MW. PSS on/PSS off.

TEST 5: Active and reactive power tests (PQ curve and Q = const)

1. PQ curve measurements

Scope of the test:

PQ chart mapping.

Test conditions:

(a) minimum % rated MW

- • Q max setpoint
- • Q min setpoint

(b) 25 % rated MW

- • Q max setpoint
- • Q min setpoint

(c) 50 % rated MW

- • Q max setpoint
- • Q min setpoint

(d) 75% rated MW

- • Q max setpoint
- • Q min setpoint

(e) 100 % rated MW

- • Q max setpoint
- • Q min setpoint

Success criteria(s):

Rfg article 18 requirements are met.

Recorded signals:

P_{330}, Q_{330}, V_{330}, P_{gen}, Q_{gen}, V_{gen}, I_{exf}, V_{exf} at sampling rate 200 ms.

Test Results

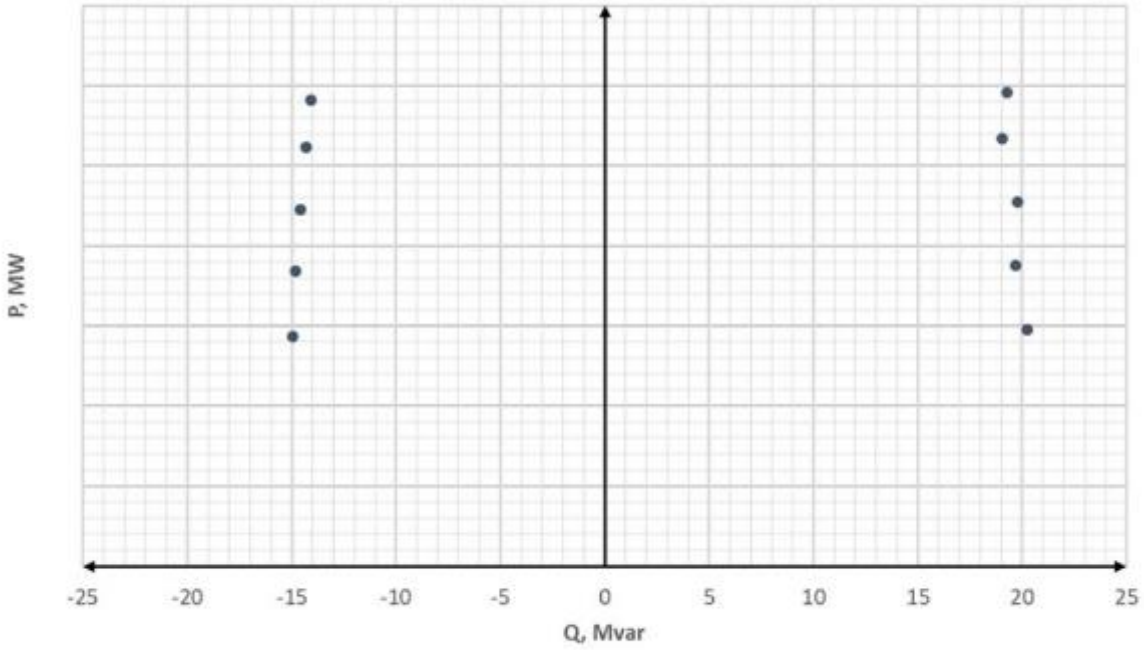
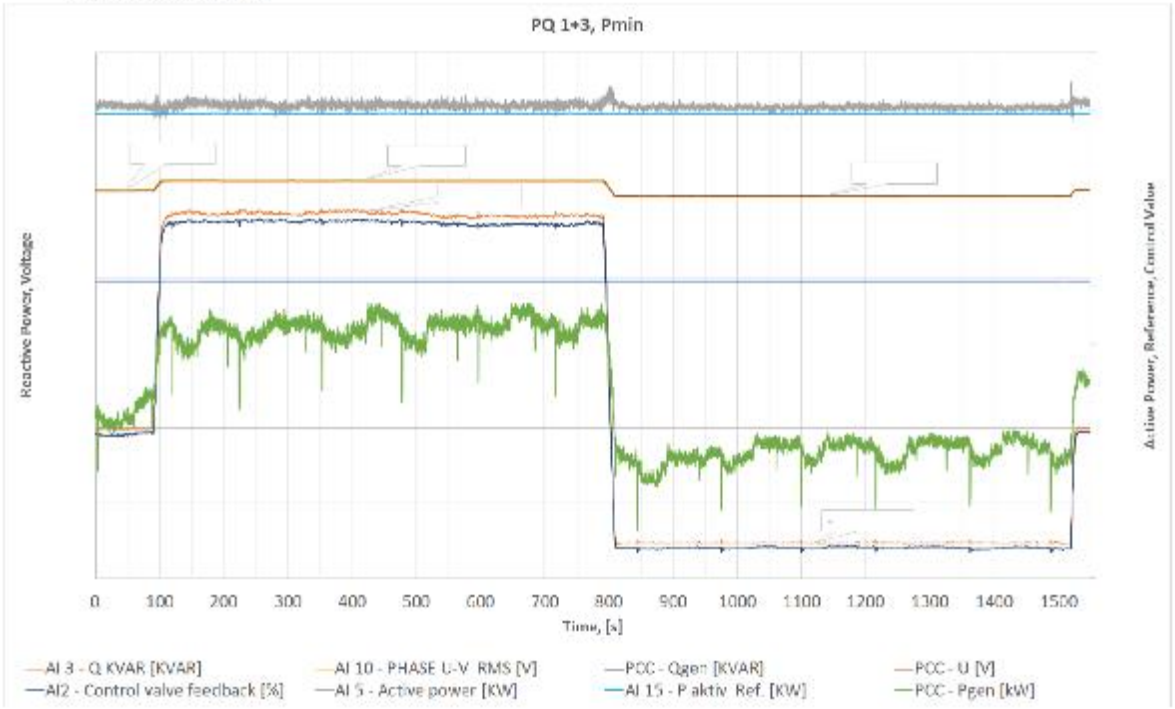


Figure 3.1. PQ diagram for Generator unit.

1.1.6. Records at Pmin



Same for each Active Power setpoint to be presented.

2. Q constant

Scope of the test:

(a) 0 MVAr
(b) -50% rated MVA
(c) +50% rated MVA

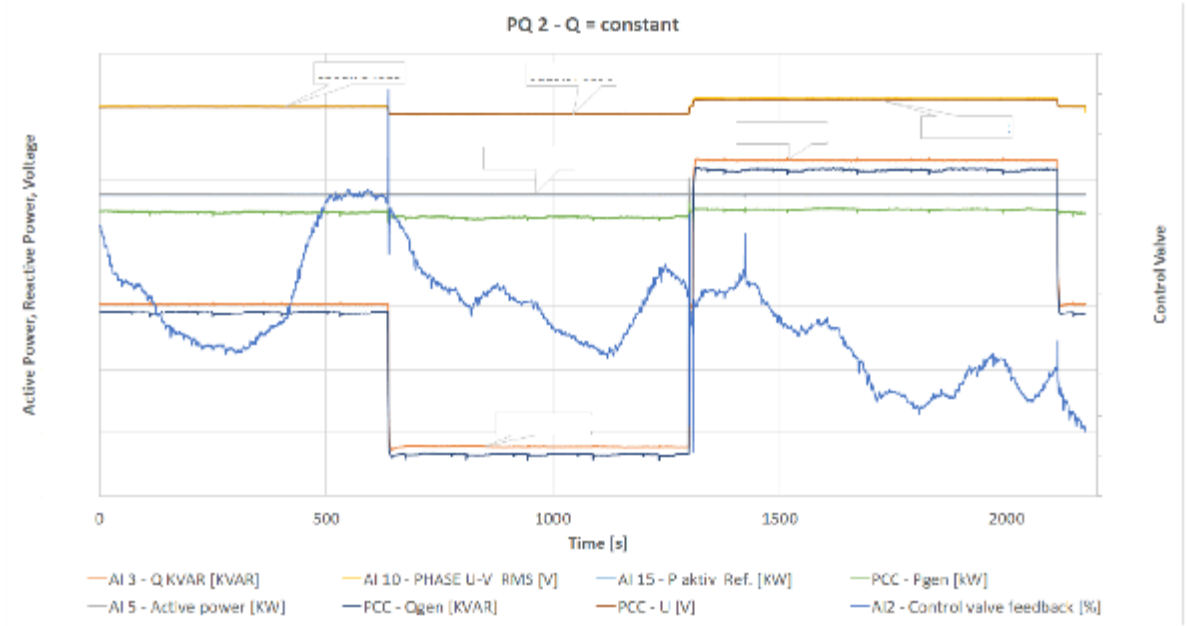
Power at each step maintained during 10 minutes.
Test repeated on both 50% Pn and 100% Pn

Success criteria(s):

Recorded signals:

Test Results

1.1.1. Records for PQ 2 Q=const (50% Pn)



TEST 6: House load test

1. House load test. Remaining load – houseload + load connected directly to power plant

Test conditions:

- Generator connected to line
- Field exciter in automatic mode
- ~50% of nominal active power (xx MW) exported by means of the link (PCC)
- Generator at max power
- House load operation 1 hour
- Resynchronisation to the grid

Test execution:

- opening of the link to transmission system

General content:

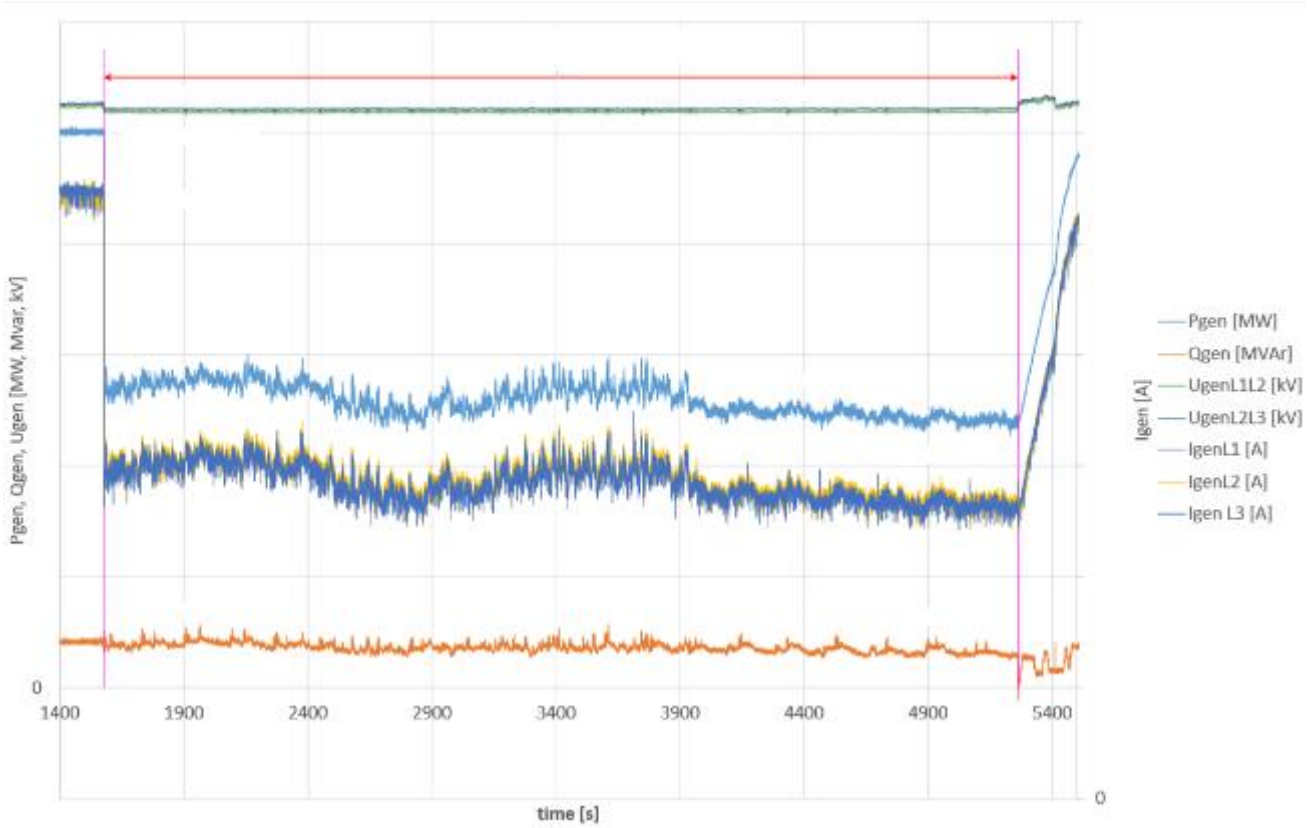
- Actual Power (Pgen)
- Actual reactive power (Qgen)
- Actual generator voltage (Ugen)
- Actual generator current (Igen)

Measured values:

Signal	Measuring range	Remarks

Igen	0 A	X A	…
Qgen	XX MVAr	XX MVAr	…
Pgen	0 MW	XX MW	…
Ugen	0 kV	X kV	…

Test results:



Record XX:XX – XX:XX

TEST 7: Over- and underfrequency

Scope of the test:

Test conditions:

Success criteria(s):

Recorded signals:

Test Results

1. Overspeed capability to stay in the range of 51.0 to 51,5 Hz for a minimum of 30 minutes

Test conditions:

Generator breaker was open, nominal voltage. The generator protection was not active during the test and the final settings not implemented.

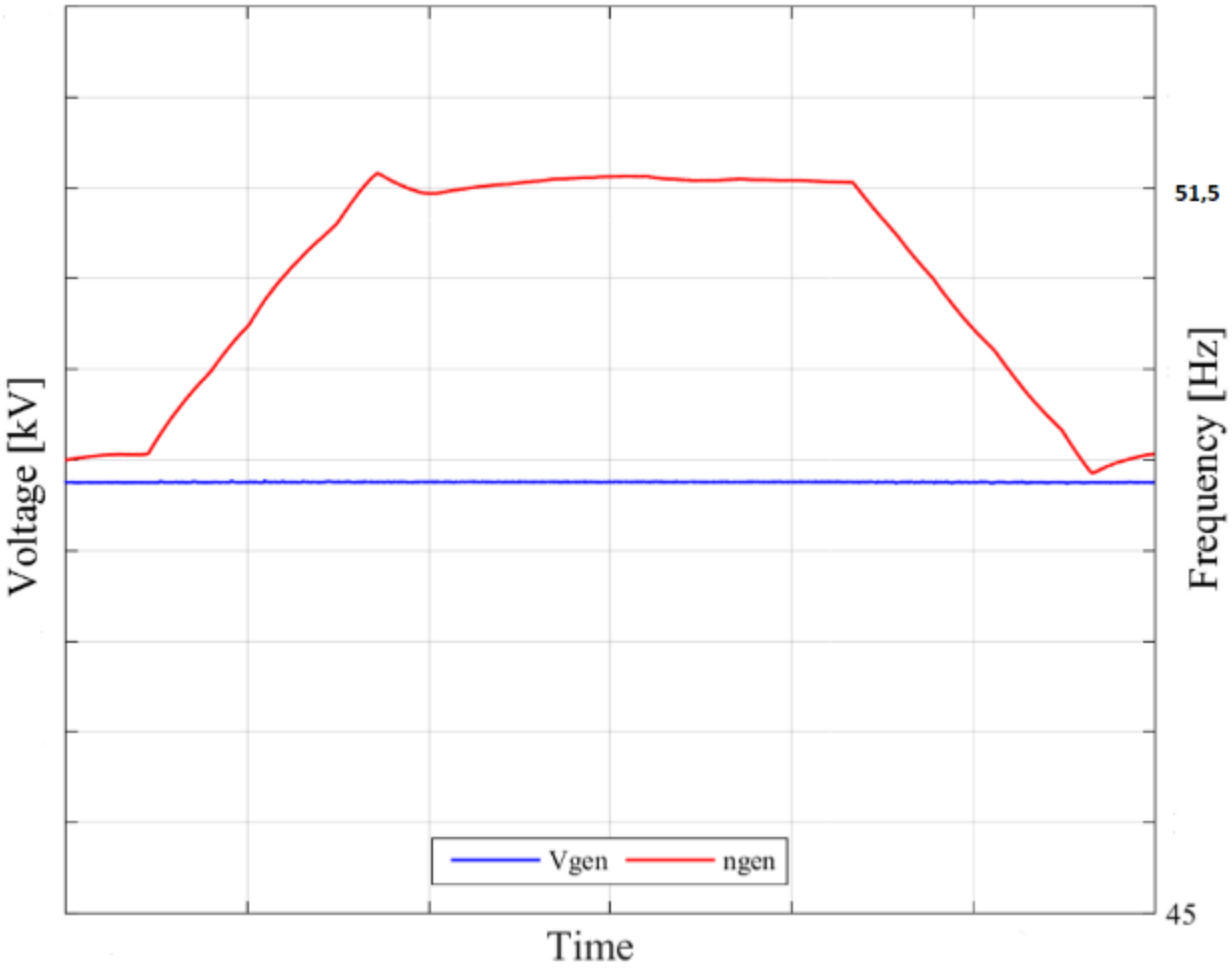
Test execution:

The speed setpoint was changed manually through the controller interface panel. Operation was performed at the frequency of 51 Hz for 30 minutes.

General content:

Sampling rate 200 ms.

Test results:



Over frequency step, the frequency is kept at 51,5 Hz for 30 minutes.

2. Underspeed capability to stay in the range of 48,5 to 47,5Hz for a minimum of 30 minutes

Test conditions:

Generator breaker was open, nominal voltage. The generator protection was not active during the test and the final settings not implemented

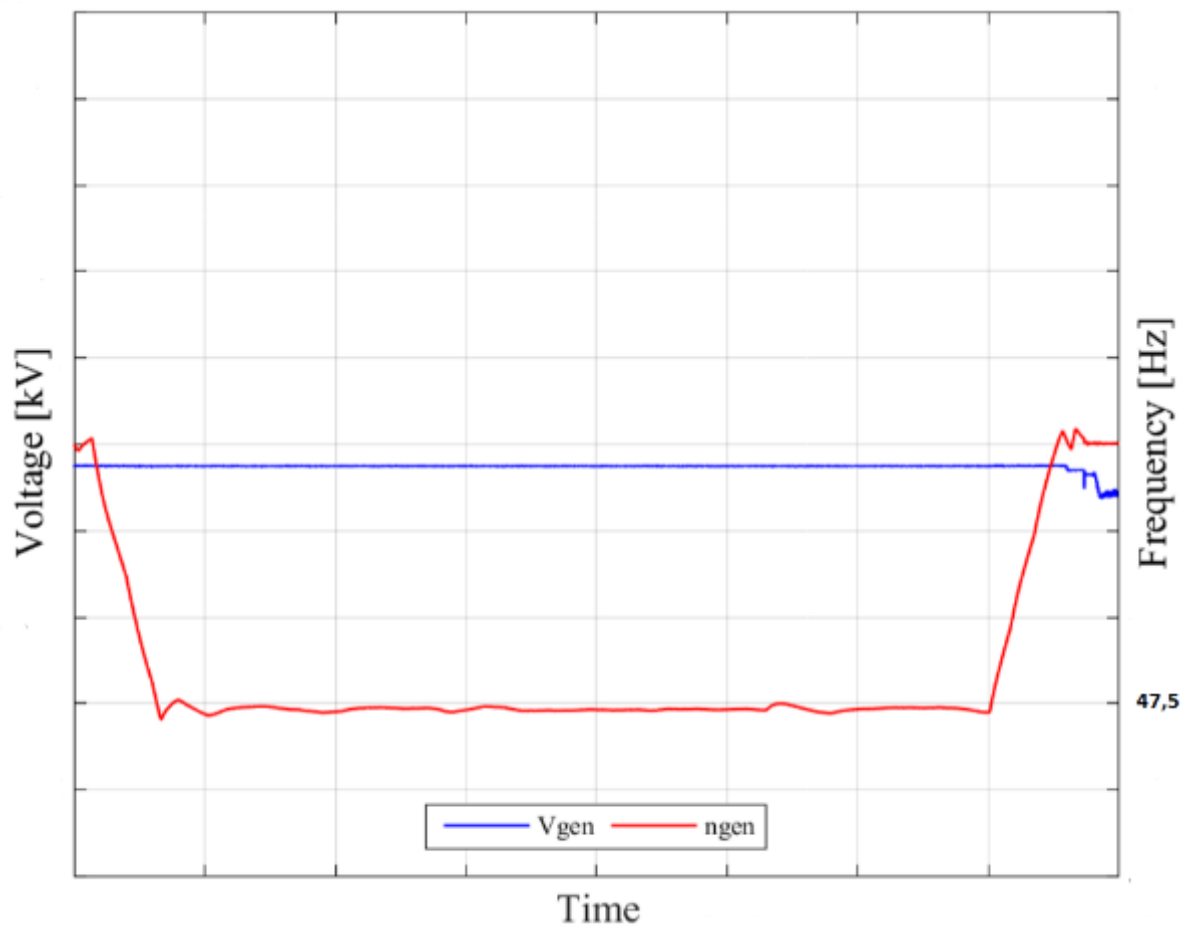
Test execution:

The speed setpoint was changed manually through the controller interface panel. Operation was performed at the frequency of 47,5 Hz for 30 minutes.

General content:

Sampling rate 200 ms.

Test results:



Under frequency step, the frequency is kept at 47,5 Hz for 30 minutes.

TEST 8: U = constant test

Scope of the test:

Test conditions:

Success criteria(s):

Recorded signals:

Test Results

Test conditions:

- Turbine synchronized

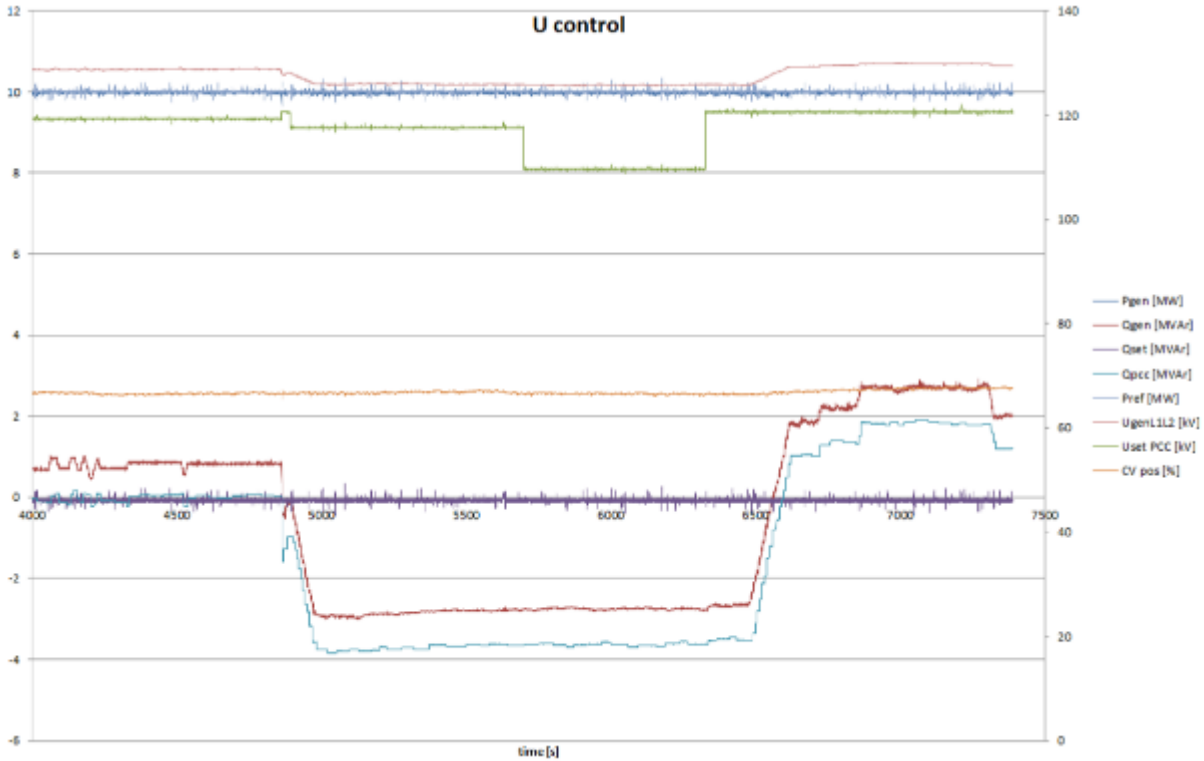
Test execution:

- Test conducted by Elering
- Each point to be held 10 minutes after stable operative achieved
    - U=const
    - Uset1=XX kV
    - Uset2=XX kV
    - Uset3=XX kV
    - Switching in and out of:
    - reactor bank in XXX substation
    - a capacitor in XXX substation

General content:

- Actual generator voltage (Ugen)
- Actual control valve position

Test results:



Second example :

Test report:

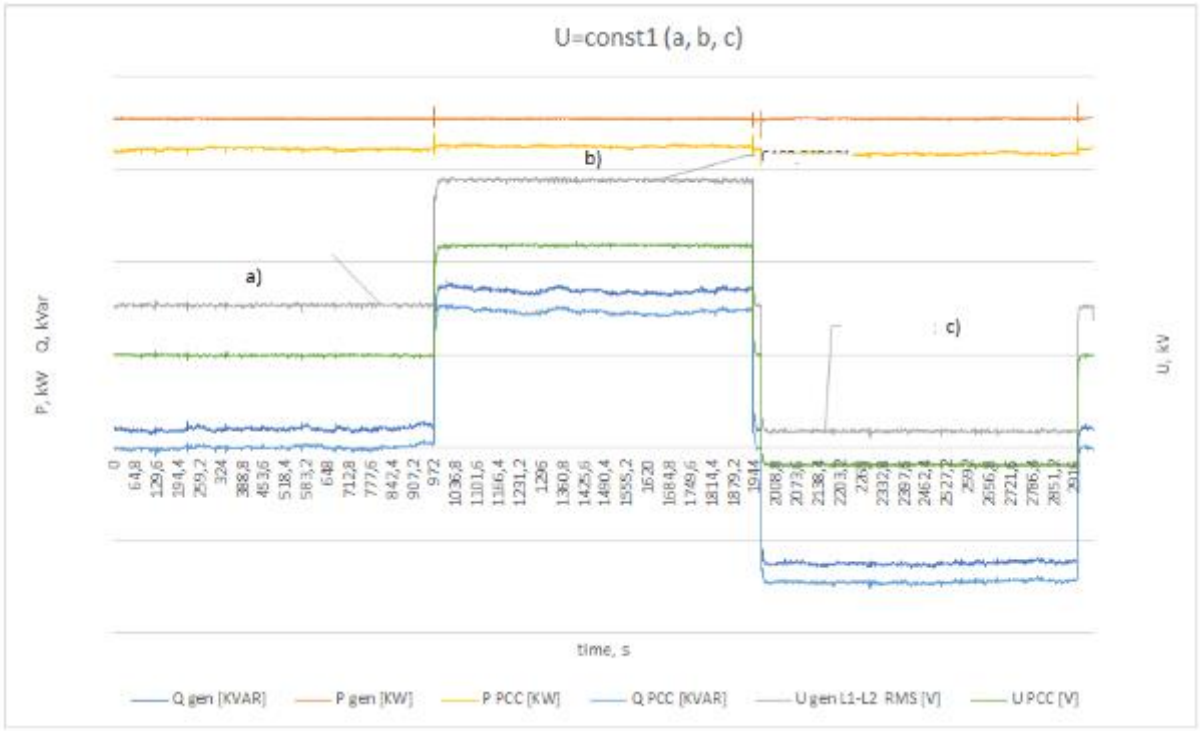
U=const 1	Time
a) U= 100%, Un= kV	
b) U= 102,5%, Un= kV	
c) U= 97,5%, Un= kV	

TEST RESULTS

Results for different generator output voltage settings are shown in table and graph below.

Table 1. Test results

Test	Setpoint, [kV]	Test begin, [hh:mm:ss]	Average value at generator terminals, [V]	Average value at PCC, [V]	Test end, [hh:mm:ss]	Value held, [hh:mm:ss]	Required, [min]	Test successful, [YES/NO]
U=const		17:39:07			17:56:05	00:16:58	00:15:00	YES
		17:56:50			18:12:12	00:15:22	00:15:00	YES
		18:13:35			18:28:46	00:15:11	00:15:00	YES



TEST 9: Load control (secondary control test)

1. Variable frequency injection into the AVR summing junction (with PSS out of service)

Test conditions:

- Turbine synchronized

Test execution:

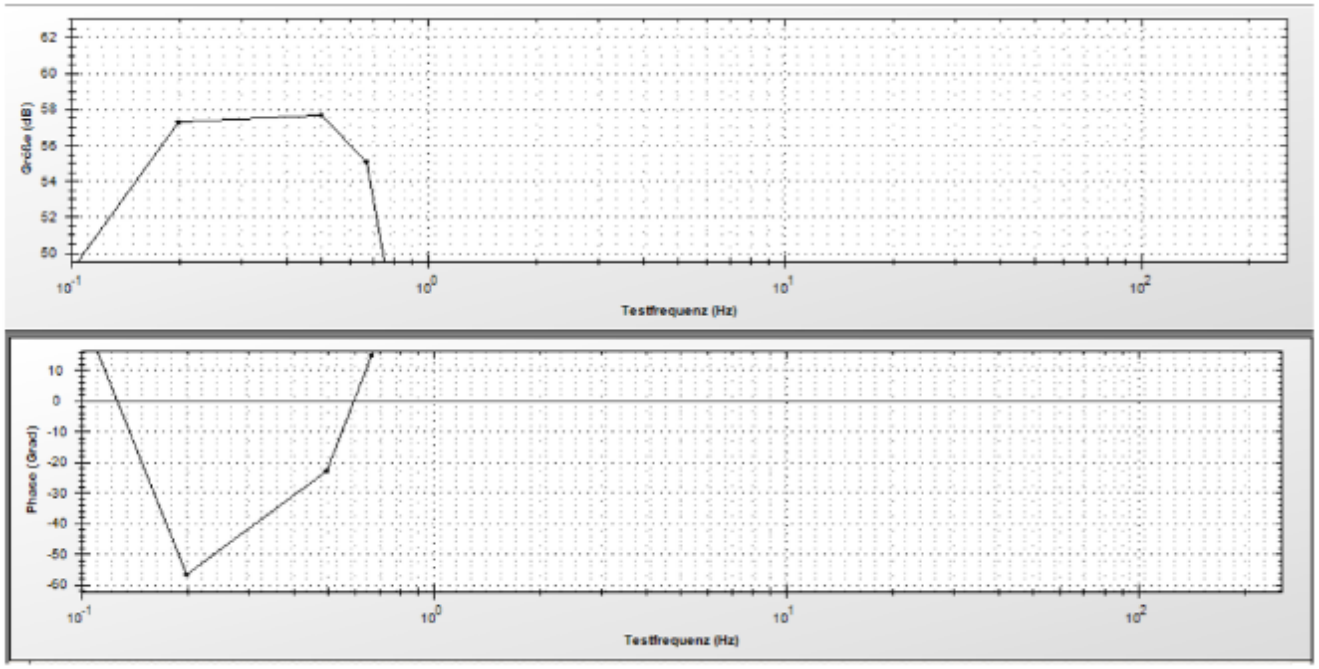
- Variable frequency injection into the AVR summing junction

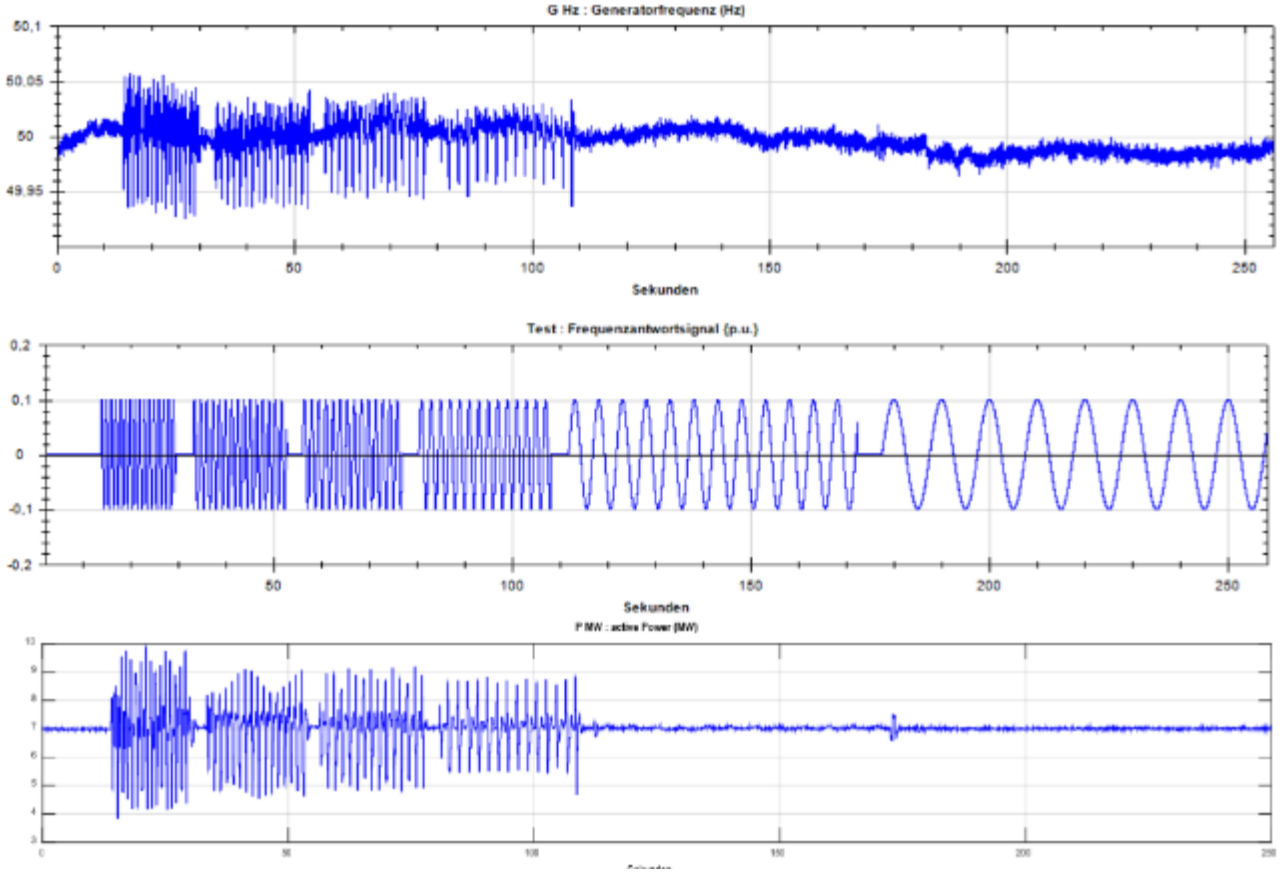
- Power System Stabilizer out of service

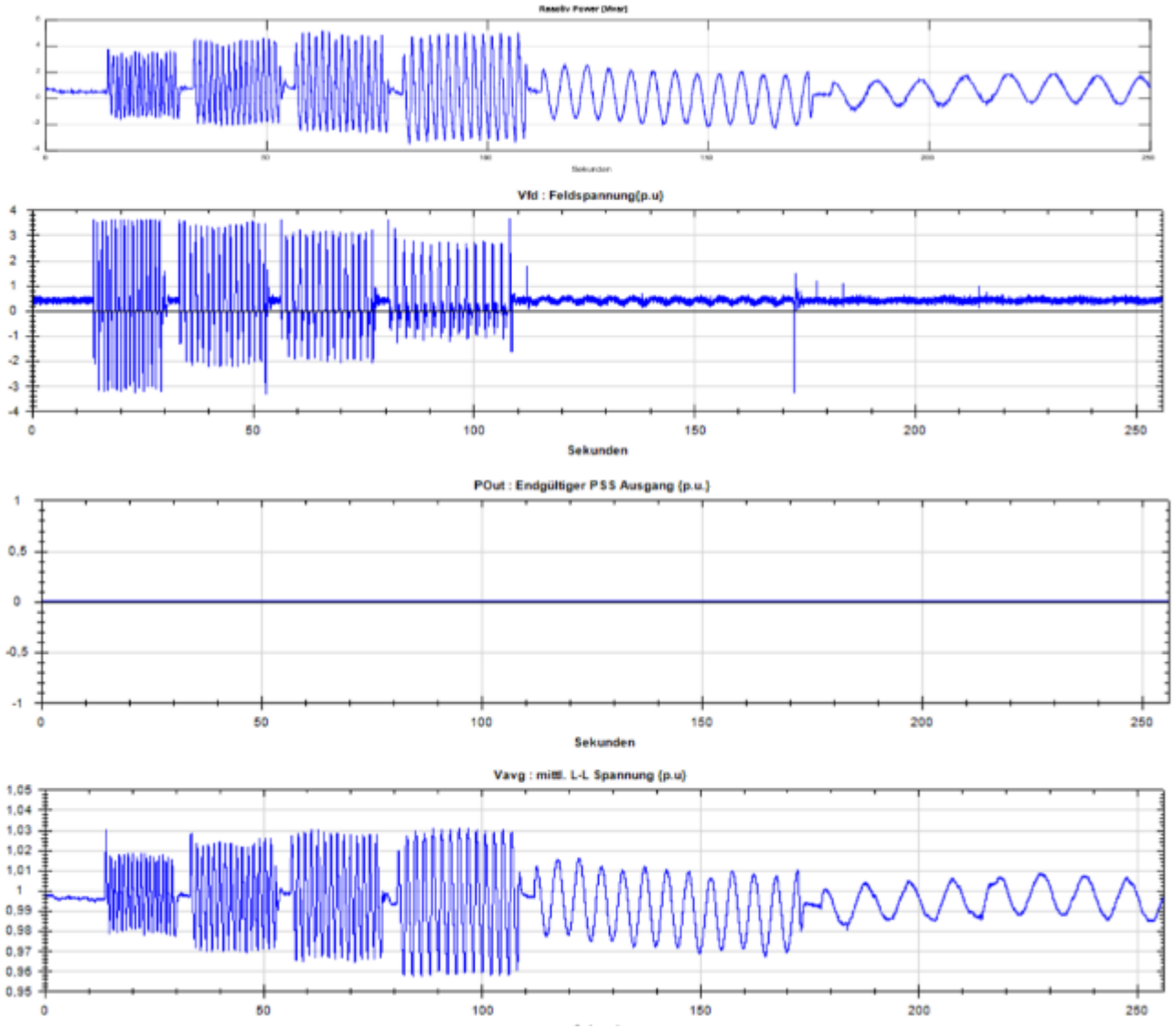
General content:

- Records from Basler DECS 250N
    - Bode diagram o Generator frequency (Hz)
    - Frequency response (p.u) o Exciter current (p.u)
    - PSS output (p.u) o Generator voltage (p.u)
    - Generator active power (MW)
    - Generator reactive power (Mvar)

Test results:

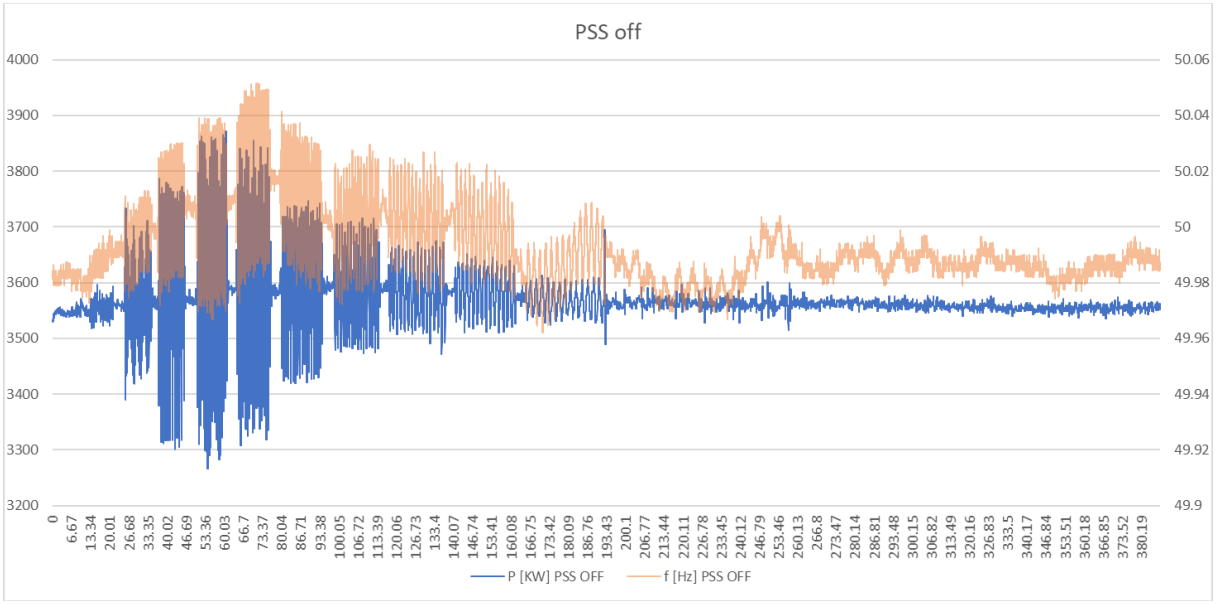


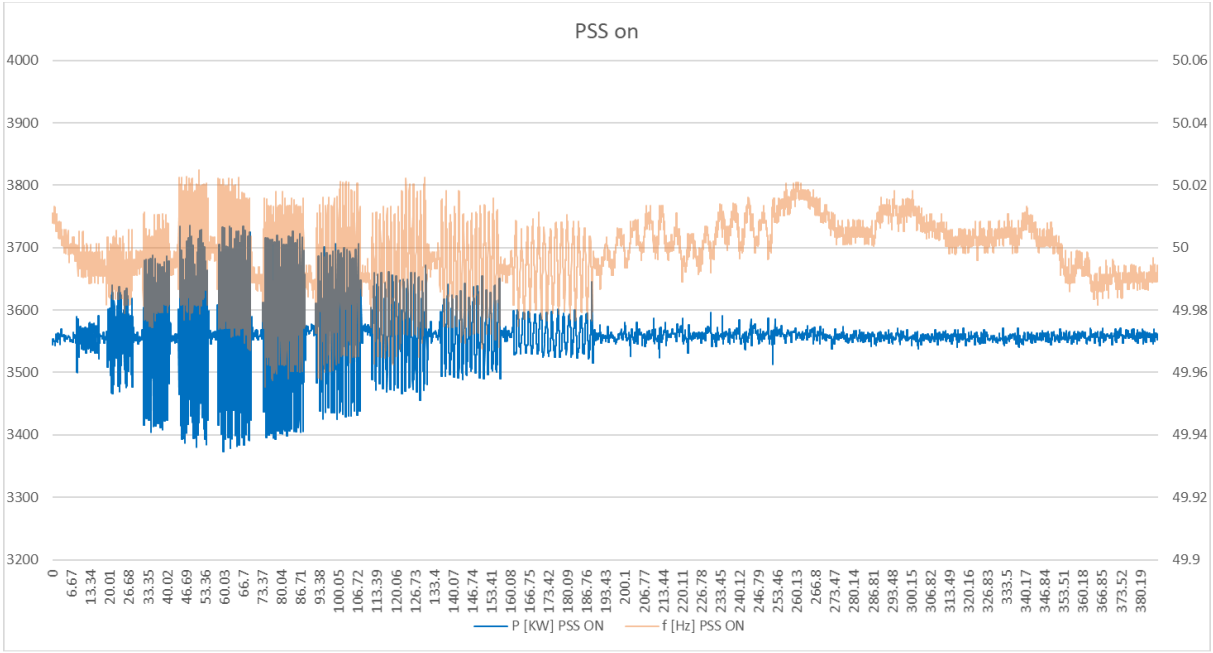

G Hz : Generatorfrequenz (Hz)
50,1
50,05
50
49,95
0
50
100
150
200
250
Sekunden
Test : Frequenzantwortsignal (p.u.)
0,2
0,1
0
-0,1
-0,2
50
100
150
200
250
Sekunden
P MW : active Power (MW)

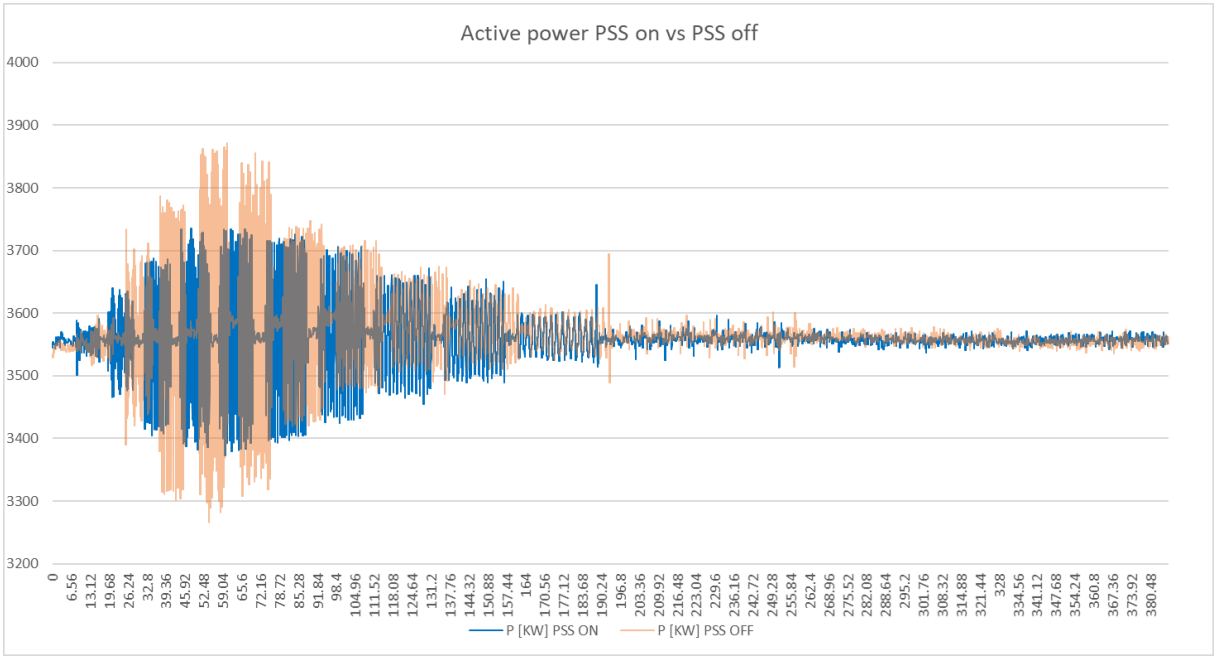


The Generator is not big enough to take any movement into the grid. Oscillation seen in the report comes from PSS test functionality of AVR.

Second example :




PSS on
4000
3900
3800
3700
3600
3500
3400
3300
3200
50.06
50.04
50.02
50
49.98
49.96
49.94
49.92
49.9
0
6.67
13.34
20.01
26.68
33.35
40.02
46.69
53.36
60.03
66.7
73.37
80.04
86.71
93.38
100.05
106.72
113.39
120.06
126.73
133.4
140.07
146.74
153.41
160.08
166.75
173.42
180.09
186.76
193.43
200.1
206.77
213.44
220.11
226.78
233.45
240.12
246.79
253.46
260.13
266.8
273.47
280.14
286.81
293.48
300.15
306.82
313.49
320.16
326.83
333.5
340.17
346.84
353.51
360.18
366.85
373.52
380.19
P [KW] PSS ON
f [Hz] PSS ON



2. Step change to governor/load reference

Test conditions:

- Turbine synchronized

Test execution:

- (a) 2.5 % step increase in MW demand signal
- (b) 2.5 % decrease in MW demand signal

General content:

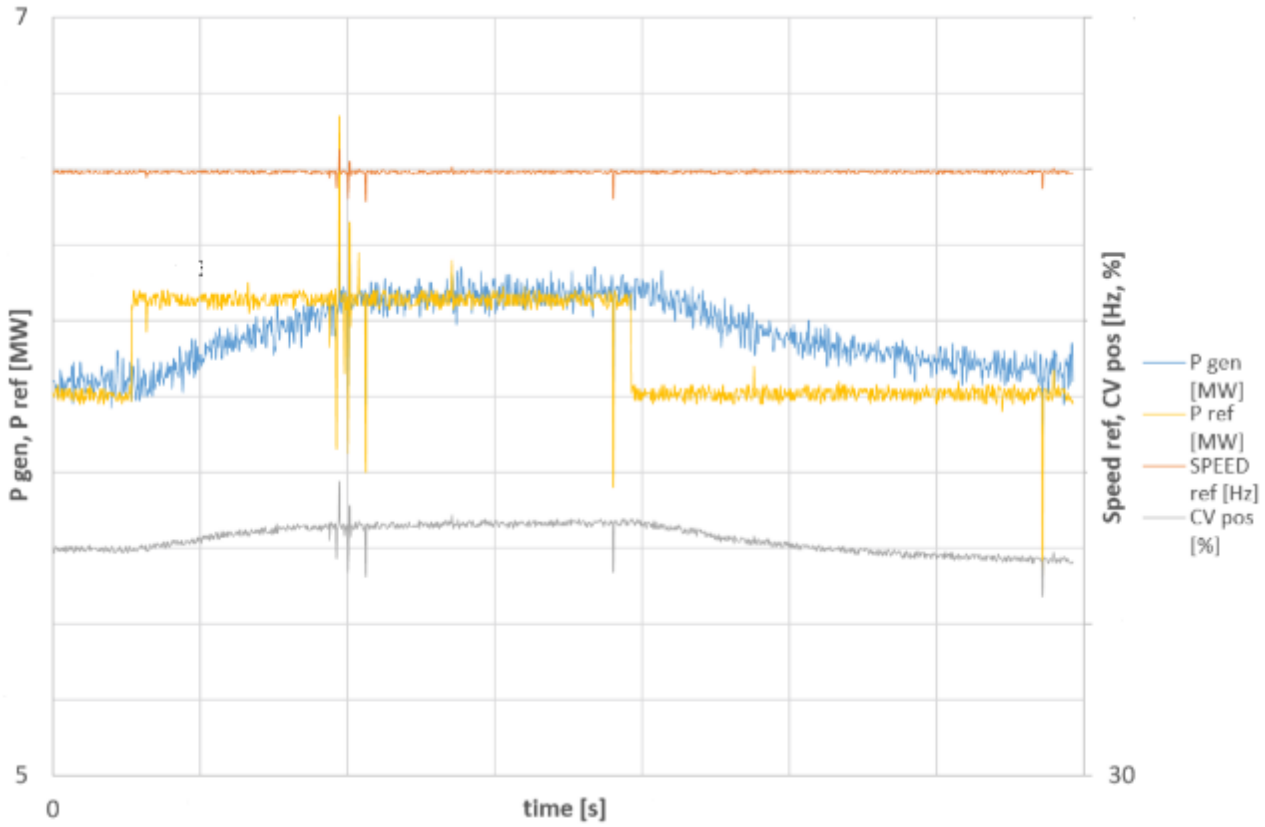
- Speed setpoint
- Actual load (Pgen)
- Actual load setpoint (Pset)

- Actual control valve position

Measured values:

Signal		Measuring range	Remarks
Pgen	0 MW	xx MW	…
Valve Position	0 %	100 %	…
Pset	0 MW	xx MW	…
Speed setpoint	0 Hz	60 Hz	…

Test results:



3. Load control (active power setpoint test; conducted by Elering if unit connected under AGC)

Test conditions:

- Generator connected to line
- Field exciter in automatic mode
- Reference for the test is for the whole production unit

Test execution:

Power output set point was changed stepwise between the different power levels shown in Table 1 from Elering control center. After each change, stable load was maintained for 10 minutes.

General General content:

- Actual generator voltage (Ugen)
- Actual reactive power (Qgen)
- Active reactive power setpoint
- Actual power (Pgen)
- Control Valve Position
- Active Power setpoint

Success criteria :

Article 15.2.(a)
the deviation between the output active power and the setpoint may be +/-5% of the nominal active power, but not more than +/- 5 MW, whichever is lower.

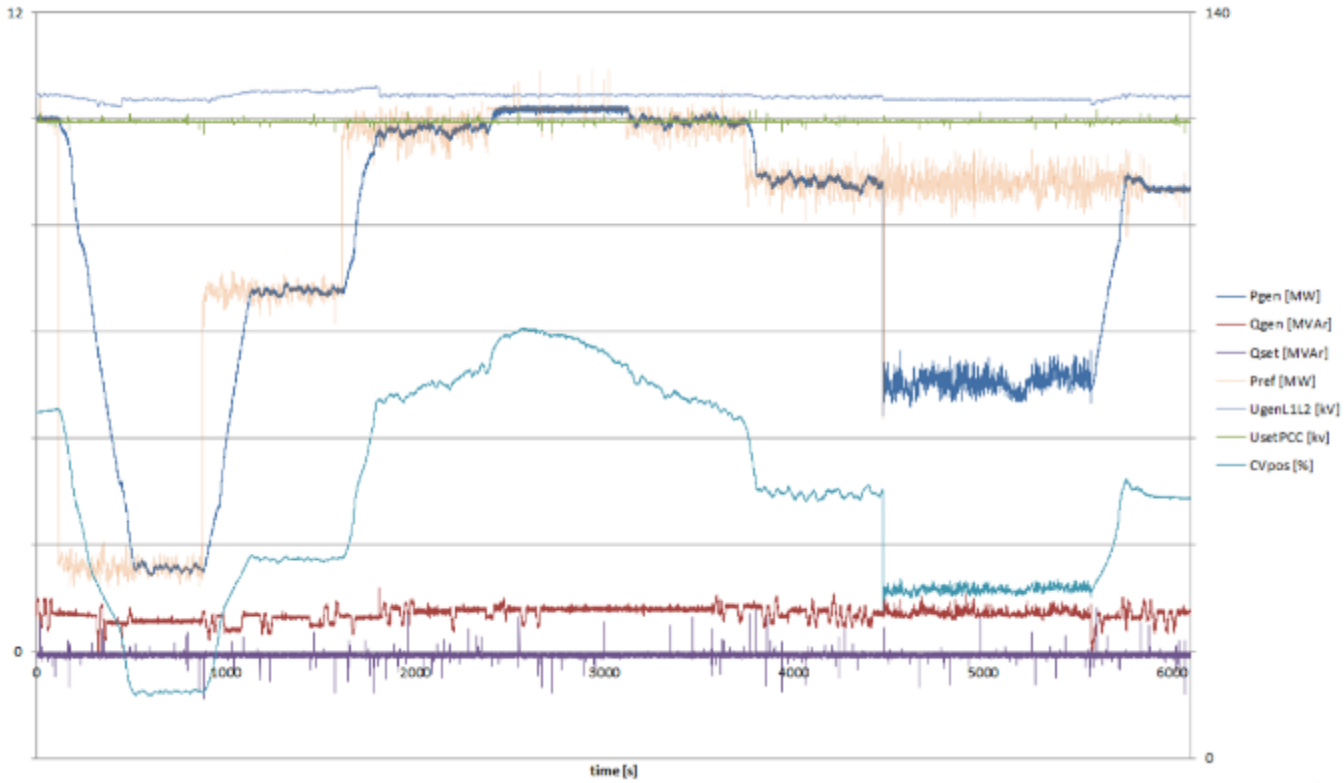
(1) Outside the ranges specified in subsections (2) to (5), it must be possible to change the output active power of the generating module within the range of constantly generated minimum and maximum capability at least at the speed of 2% Pn/min.

(3) It must be possible to change the active power of a generating module powered by a steam turbine or a combined cycle at the speed of at least 4% of nominal power per minute. It must be possible to change the power at this speed to the extent of 30% in the range of 60–90% of the device’s nominal power. In certain cases, the percentage of change can be 20. If this is possible with the devices, the power may be changed at the maximum admissible power regulation speed also if it’s below 60% or over 90% of nominal power.

Test results:

Table 3.

Load set point, [MW]	**Test begin, [hh:mm]**	**Change, [MW]**	**Change, [%]**	**Actual load reached [hh:mm]**	**Duration, [hh:mm]**	**Grid code, [min]**	**Test successful, [YES/NO]**
x	14:37:06	x	84%	14:43:38	**0:06:32**	**x**	**YES**
x	14:49:47	x	52%	14:54:00	**0:04:13**	**x**	**YES**
x	15:02:05	x	29%	15:05:03	**0:02:58**	**x**	**YES**
x	15:14:50	x	3%	15:15:25	**0:00:35**	**x**	**YES**
x	15:27:08	x	-3%	15:27:57	**0:00:49**	**x**	**YES**
x	15:37:34	x	-10%	15:38:35	**0:01:02**	**x**	**YES**



Second example :

Table 2. Event table for test S13 **Event no.**	**Time**	**Measured P_{PCC}, [MW]**	**Setpoint P_{PCC}, [MW]**
1	08:31:00 – 08:44:38	x	x
2	08:44:38 – 09:10:20	x	x
3	09:10:20 – 09:28:55	x	x
4	09:28:55 – 09:43:22	x	x
5	09:43:22 – 09:57:51	x	x

6	09:57:51 – 10:17:07	x	x
7	10:17:07 – 11:04:19	x	x
8	11:04:19 – 12:05:14	x	x

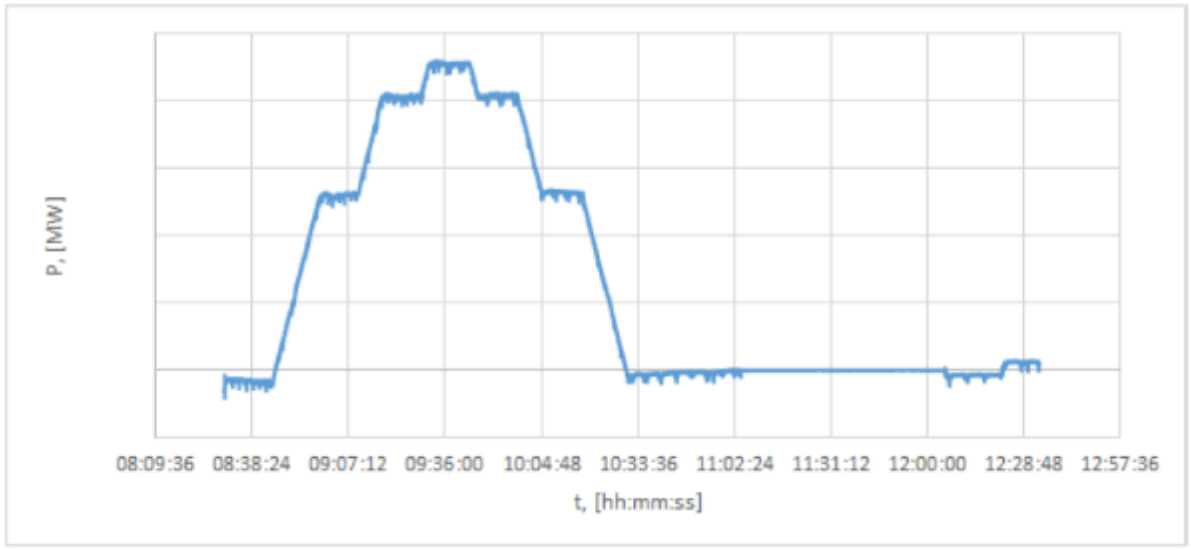


Figure 1. Overall graph of the test

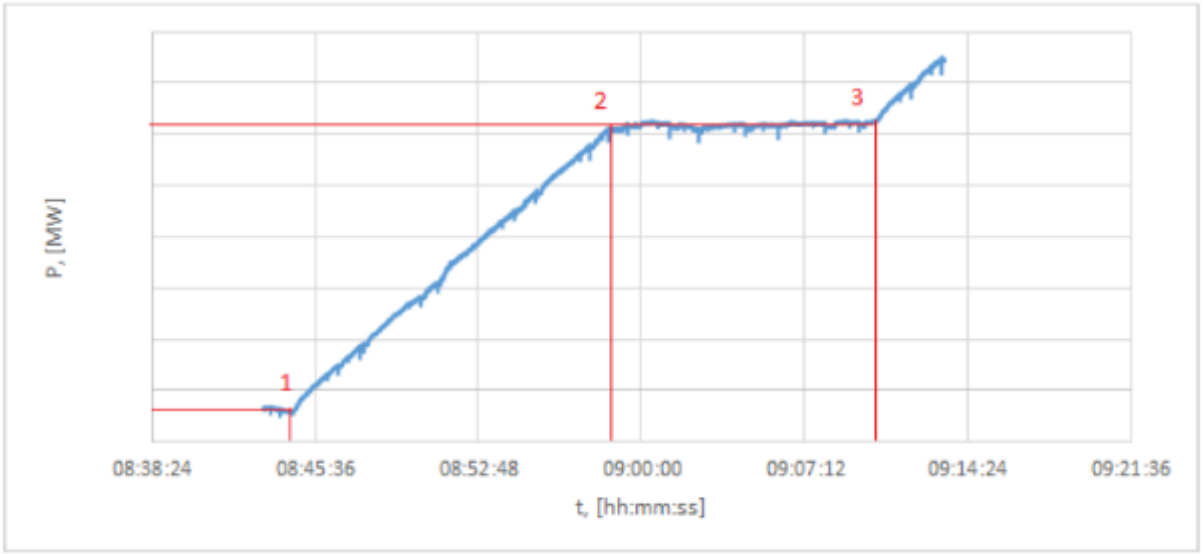


Figure 2. First ramp. Such graphs for every ramp.

Event	t, [hh:mm:ss]			P_{PCC}, [MW]		
	1	2	3	1	2	3
1	-	08:31:00	08:44:38			
2	08:44:38	08:58:28	09:10:20			
3	09:10:20	09:17:25	09:28:55			
4	09:28:55	09:31:20	09:43:22			
5	09:43:22	09:45:55	09:57:51			
6	09:57:51	10:04:40	10:17:07			
7	10:17:07	10:30:40	11:04:18			
8	11:04:19	12:05:14	-			-

Event	Δt_1 (t_2-t_1), [s]	Δt_2 (t_3-t_2), [s]	ΔP_{PCC} ($P_2 - P_1$), [MW]	$\Delta P_{PCC}/\ \Delta t_1$,
1	-	818	-	0
2	830	712		
3	425	690		
4	145	722		
5	153	716		
6	409	747		
7	813	2018		
8	3655 (1h 55s)	-	0	0

TEST 10: Primary control test including LFSM-O and LFSM-U

Test conditions:

Test execution:

The step changes where implemented by altering the simulated generator frequency to the governor in the turbine control system. After applying the step change, the frequency was kept at the new level for given time after the active power had stabilized. Between each step the frequency step was reset to 0 mHz. After resetting the frequency, it was kept at 0 mHz for 1 or 2 minutes after the active power had stabilized before applying the next step. Droop and deadband changes were made by the power plant operator. Steps exceeding 500 mHz engaged the Emergency mode.

Success criteria:

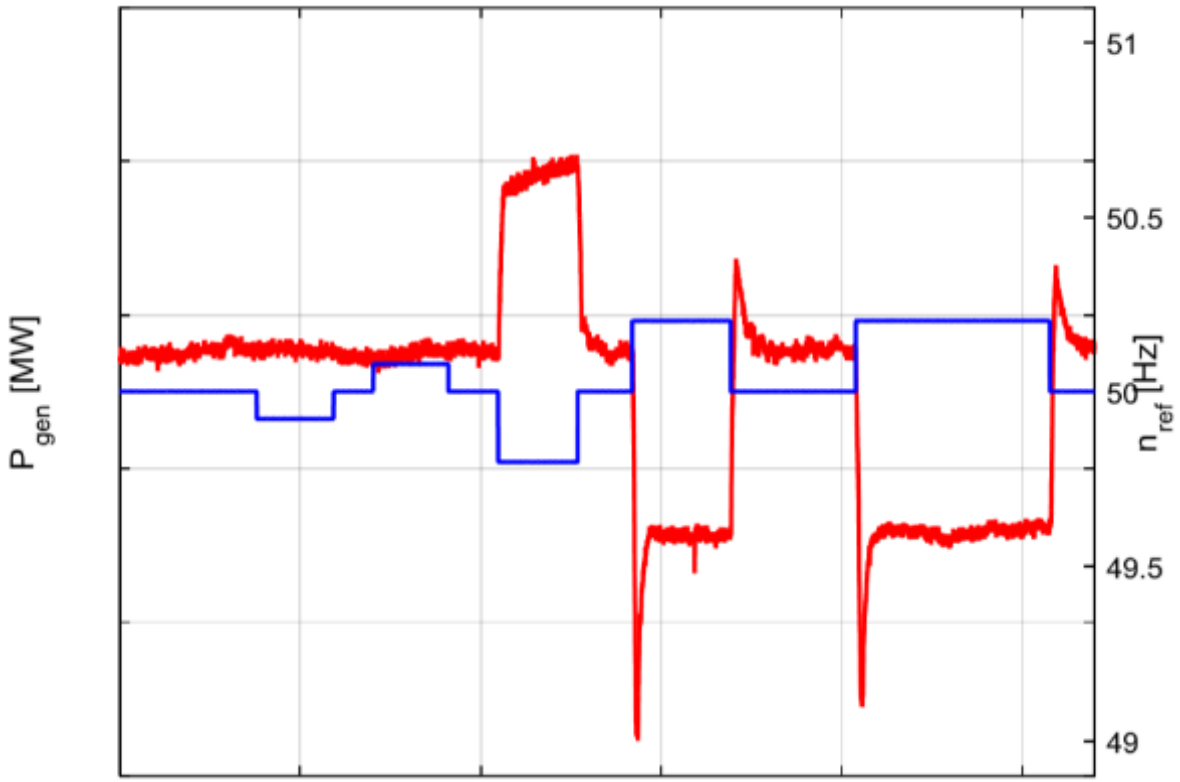
Production unit primary control range (primary reserve) must be at least ±10% of the rated power (± 1.05 MW). Production equipment shall obtain the required primary reserve power within 30 seconds, 50% of it within 10 seconds, and be able to maintain the primary reserve power for at least 15 minutes.

Test results:

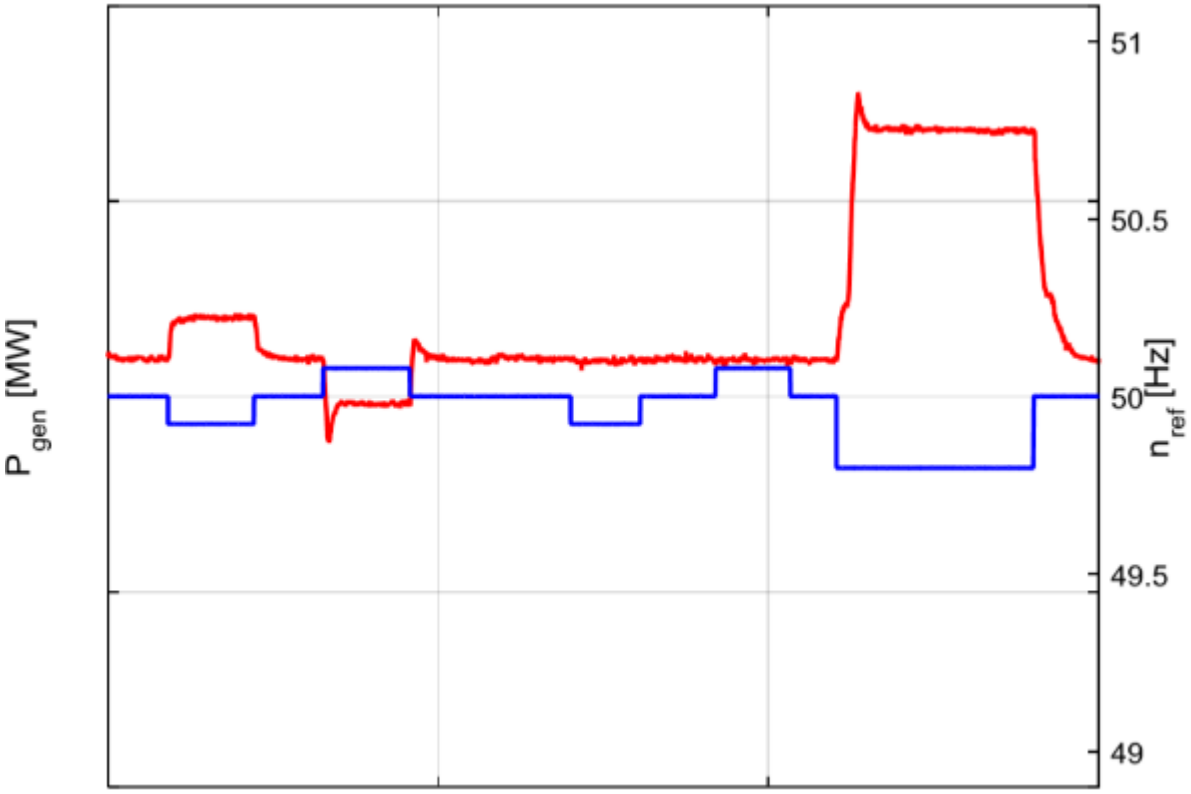
40% output:

No.	Freq. control enabled	Droop (%)	Deadband (mHz)	Frequency step (mHz) (all changes from 50 Hz)	Minimum duration (after stabilized output) (min)	Measured ΔP after 10 s (MW)	Measured ΔP after 30 s (MW)	Measured ΔP when stable (MW)
1	Yes	8	100	-80	2	X	X	X
2	Yes	8	100	80	2	X	X	X
3	Yes	8	100	-200	2	X	X	X
4	Yes	8	100	200	5	X	X	X
5	Yes	8	0	-80	2	X	X	X
6	Yes	8	0	80	2	X	X	X
7	Yes	2	100	-80	2	X	X	X
8	Yes	2	100	80	2	X	X	X
9	Yes	2	100	-200	5	X	X	X
10	Yes	2	100	200	2	X	X	X
11	Yes	2	0	-80	2	X	X	X
12	Yes	0	0	80	2	X	X	X
13	No	8	0	-450	2	X	X	X
14	No	8	0	450	2	X	X	X
15	No	8	0	-550	15	X	X	X

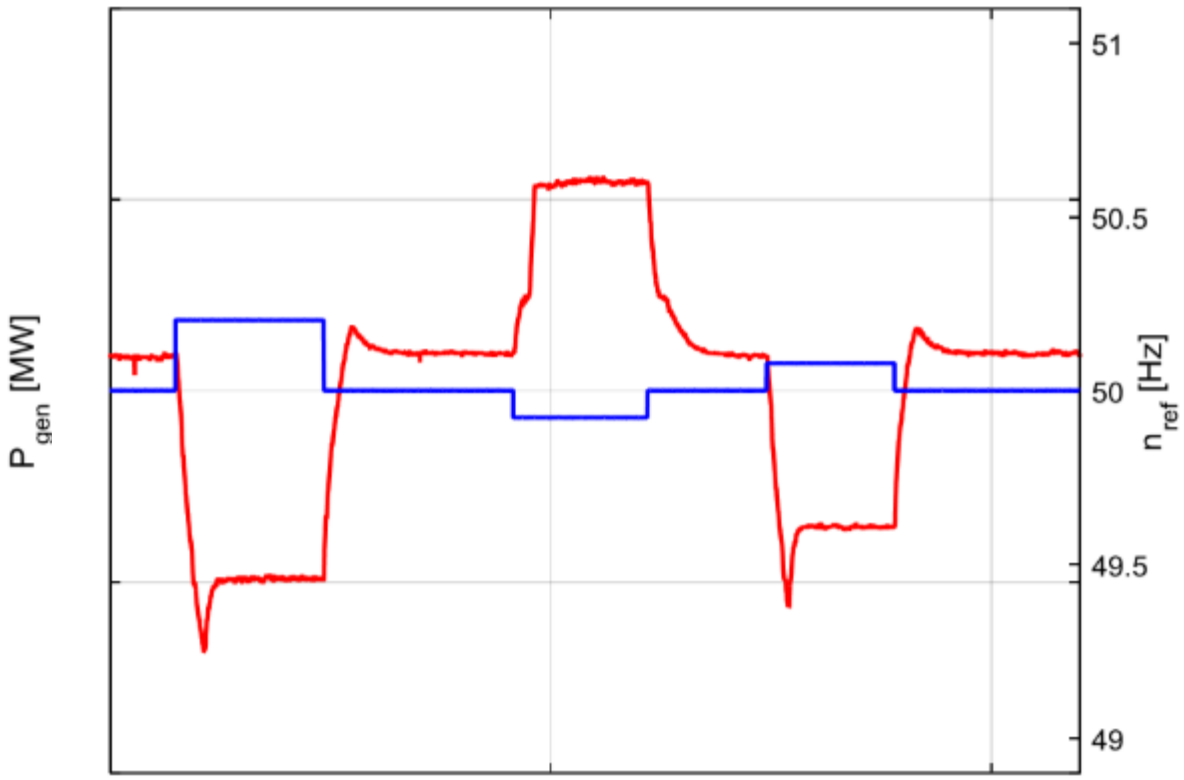
16	No	8	0	550	2	X	X	X
17	No	8	0	-1000	2	X	X	X
18	No	8	0	1000	2	X	X	X
19	No	2	0	-450	2	X	X	X
20	No	2	0	450	2	X	X	X
21	No	2	0	-550	2	X	X	X
22	No	2	0	550	15	X	X	X



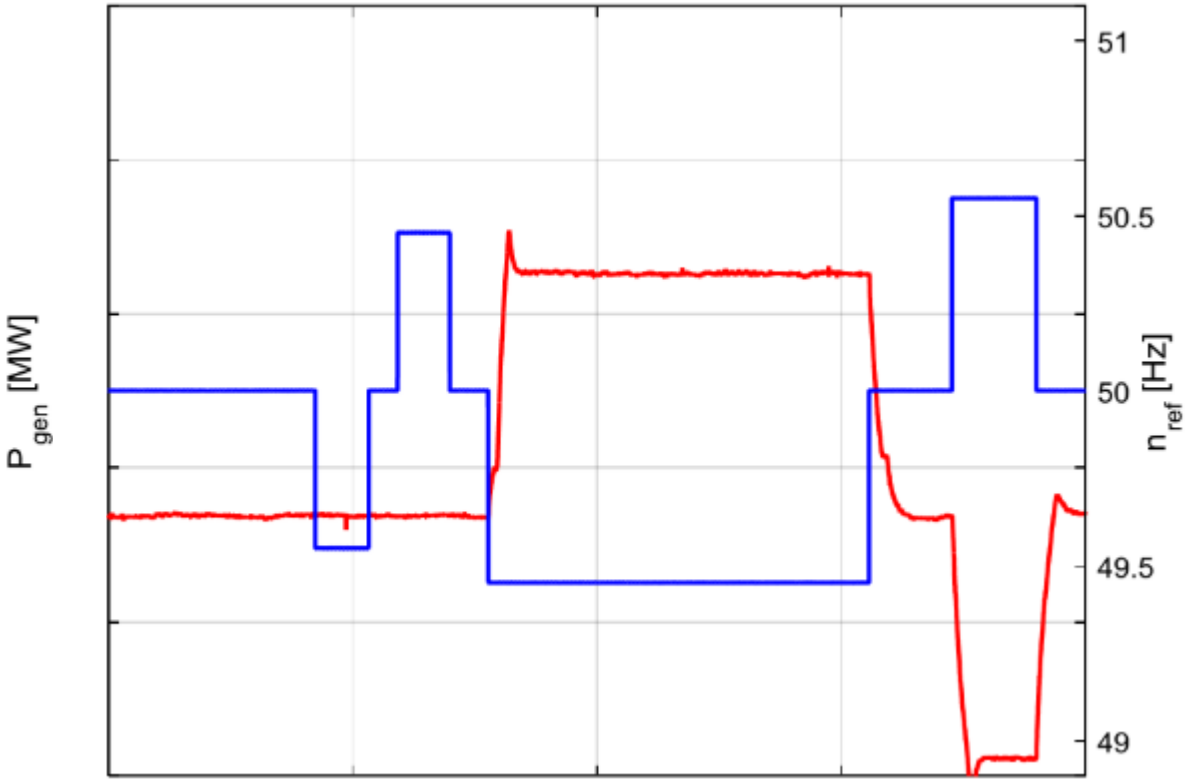
Generator active power and frequency reference when steps 1-4 are applied, the last step is done twice.



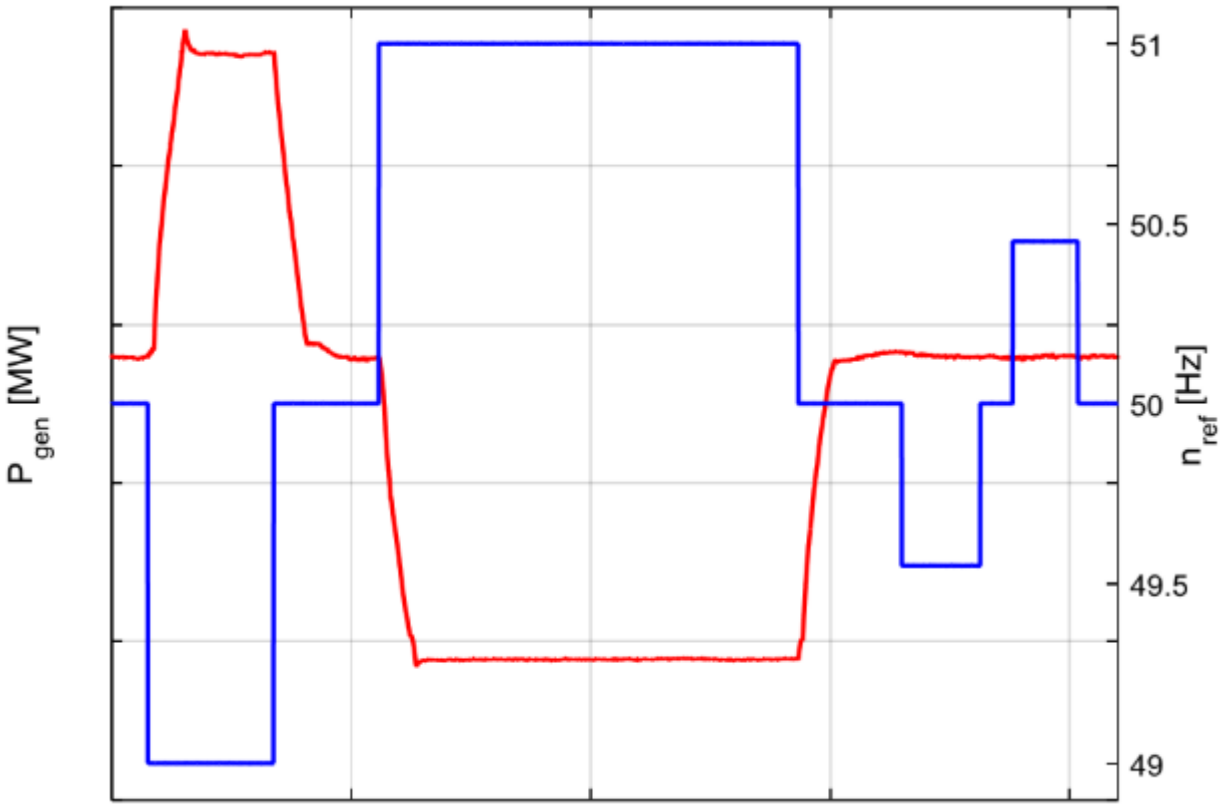
Generator active power and frequency reference when steps 5-9 are applied.



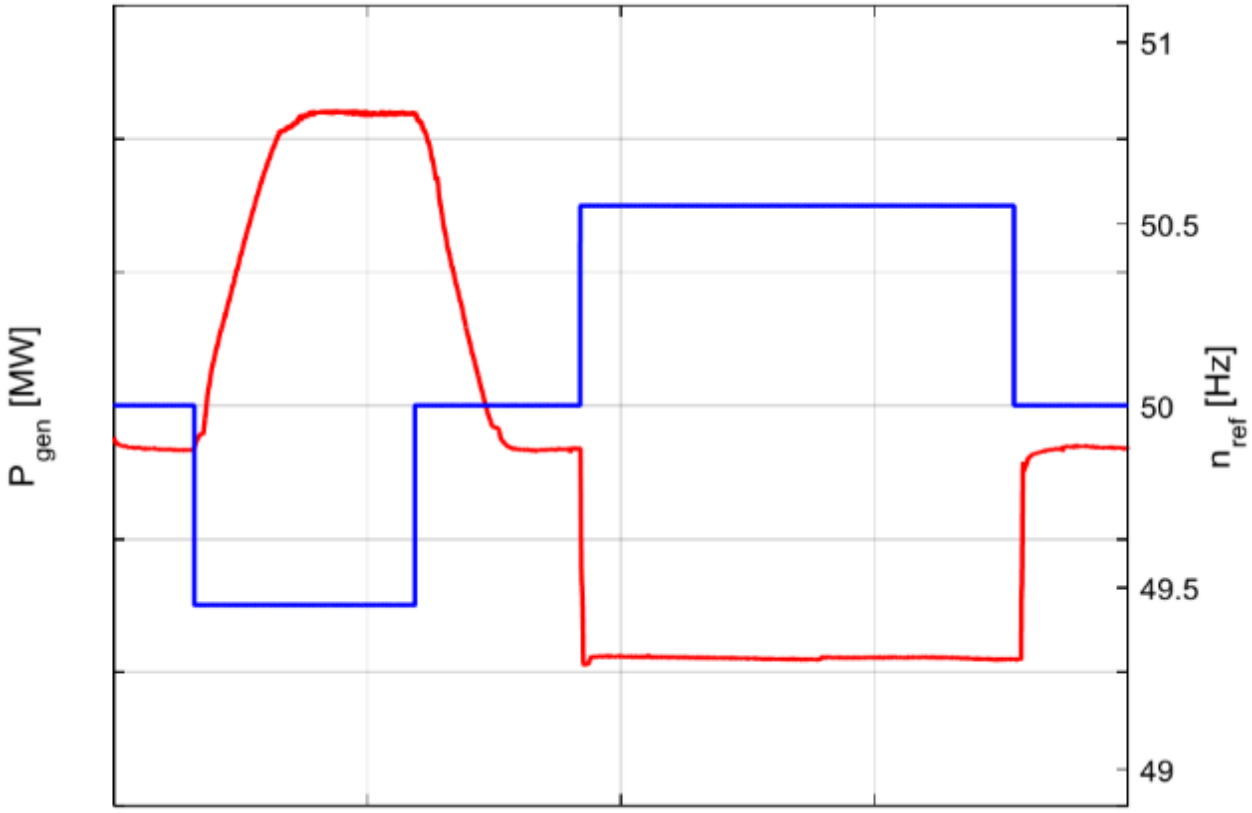
Generator active power and frequency reference when steps 10-12 are applied.



Generator active power and frequency reference when steps 13-16 are applied.



Generator active power and frequency reference when steps 17-20 are applied.



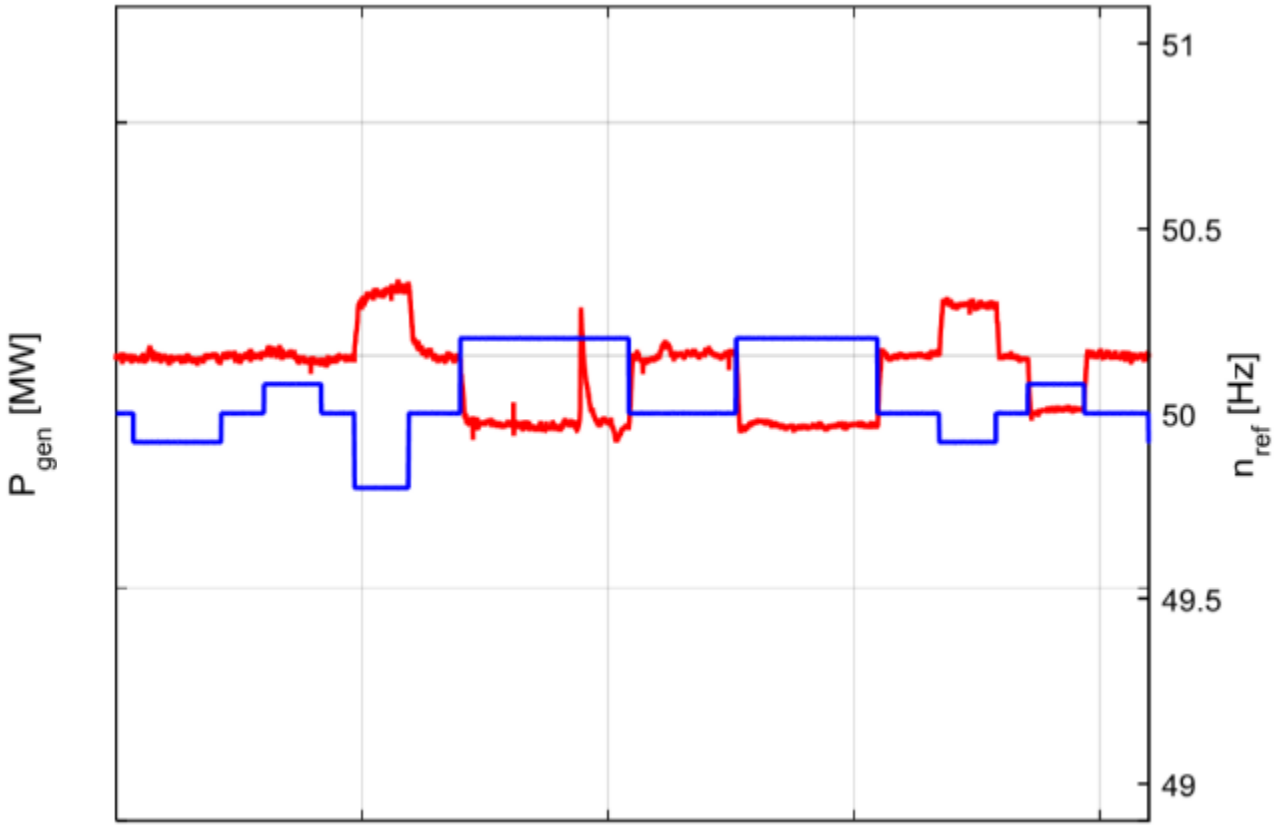
Generator active power and frequency reference when steps 21-22 are applied.

90% output:

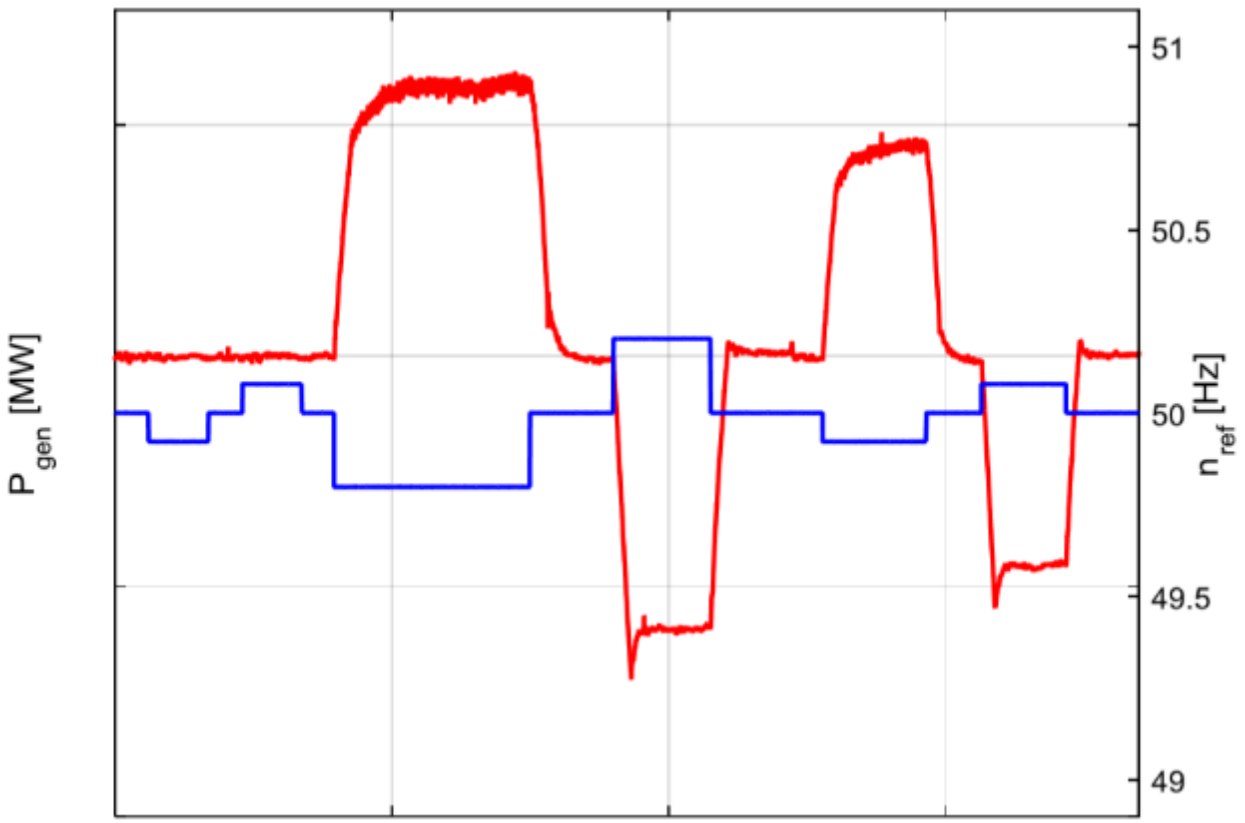
No.	Freq. control enabled	Droop (%)	Deadband (mHz)	Frequency step (mHz) (all changes	Minimum duration (after stabilized	Measured ΔP after 10 s (MW)	Measured ΔP after 30 s (MW)	Measured ΔP when stable (MW)

				from 50 Hz	output) (min)			
1	Yes	8	100	-80	2	X	X	X
2	Yes	8	100	80	2	X	X	X
3	Yes	8	100	-200	2	X	X	X
4	Yes	8	100	200	5	X	X	X
5	Yes	8	0	-80	2	X	X	X
6	Yes	8	0	80	2	X	X	X
7	Yes	2	100	-80	2	X	X	X
8	Yes	2	100	80	2	X	X	X
9	Yes	2	100	-200	5	X	X	X
10	Yes	2	100	200	2	X	X	X
11	Yes	2	0	-80	2	X	X	X
12	Yes	2	0	80	2	X	X	X
13	No	8	0	-450	2	X	X	X
14	No	8	0	450	2	X	X	X
15	No	8	0	-550	15	X	X	X
16	No	8	0	550	2	X	X	X
17	No	8	0	-1000	2	X	X	X
18	No	8	0	1000	15	X	X	X

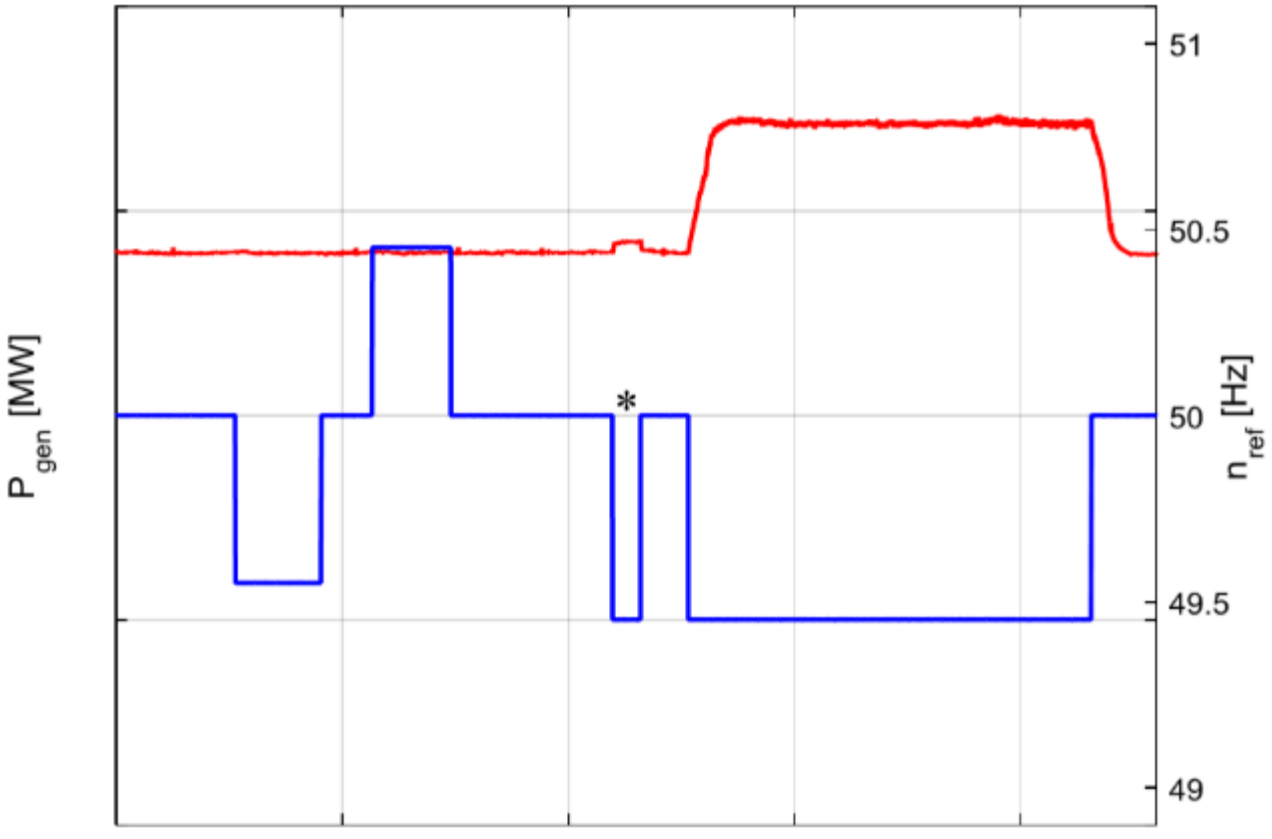
19	No	8	0	-450	2	X	X	X
20	No	2	0	450	2	X	X	X
21	No	2	0	-550	2	X	X	X
22	No	2	0	550	15	X	X	X



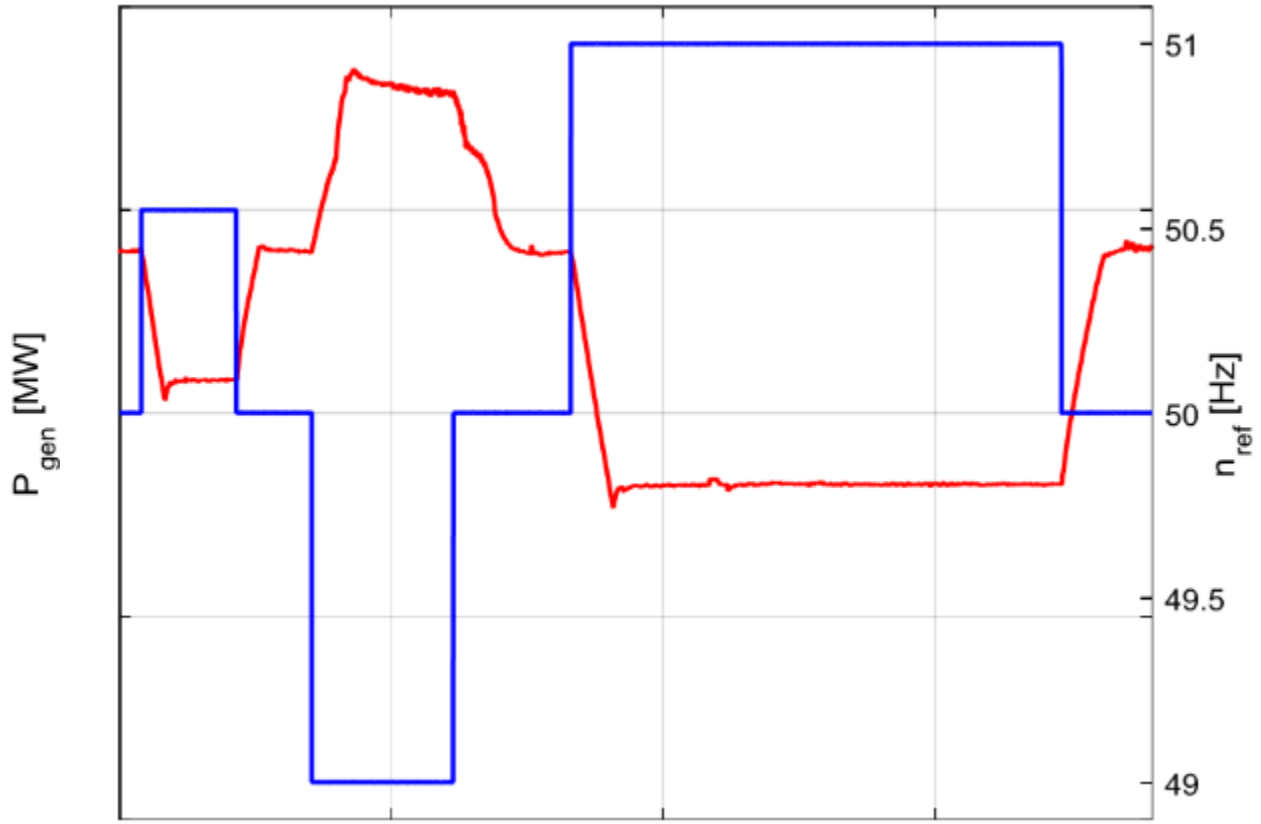
Generator active power and frequency reference when steps 1-6 are applied. Step 4 is done twice in a row.



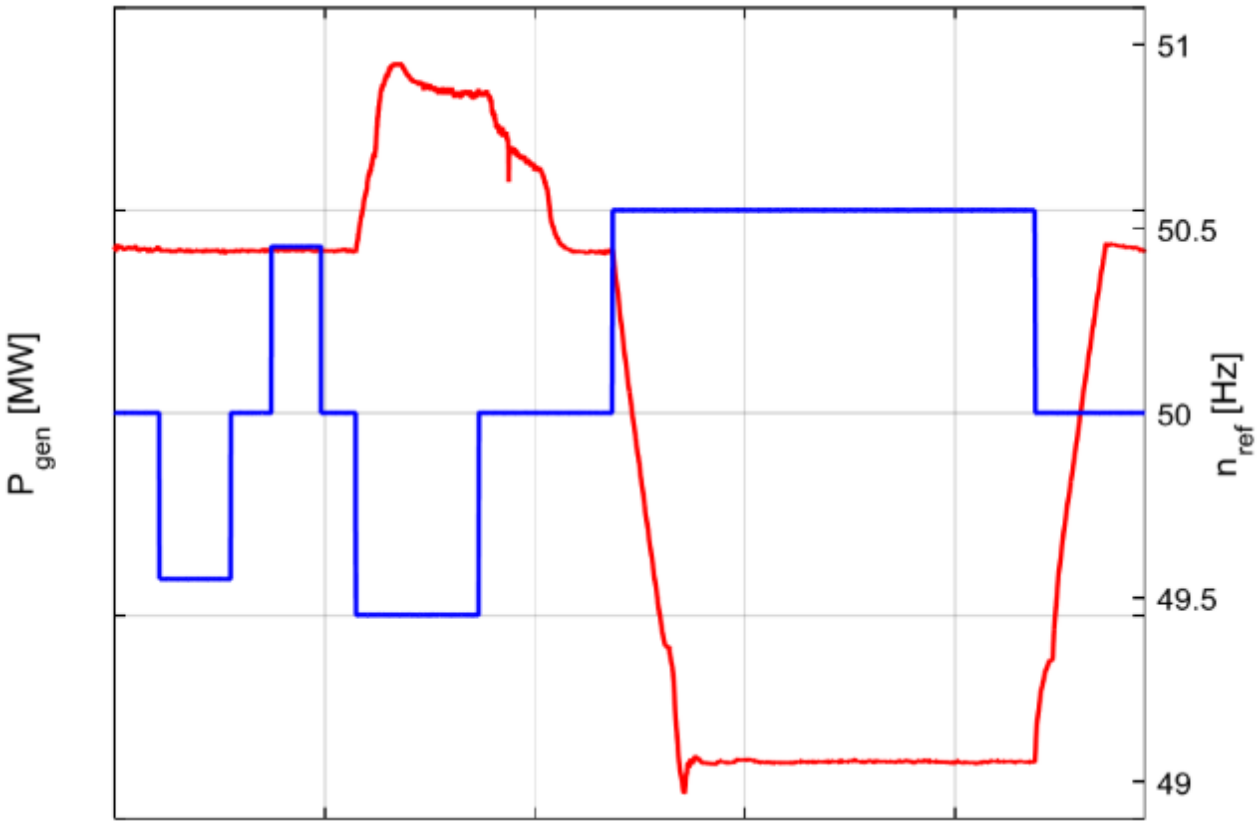
Generator active power and frequency reference when steps 7-12 are applied.



Generator active power and frequency reference when steps 13-15 are applied. (*indicates a step test that is repeated since the emergency reserve was not enabled the first time due to a mistake in governor handling)



Generator active power and frequency reference when steps 16-18 are applied.

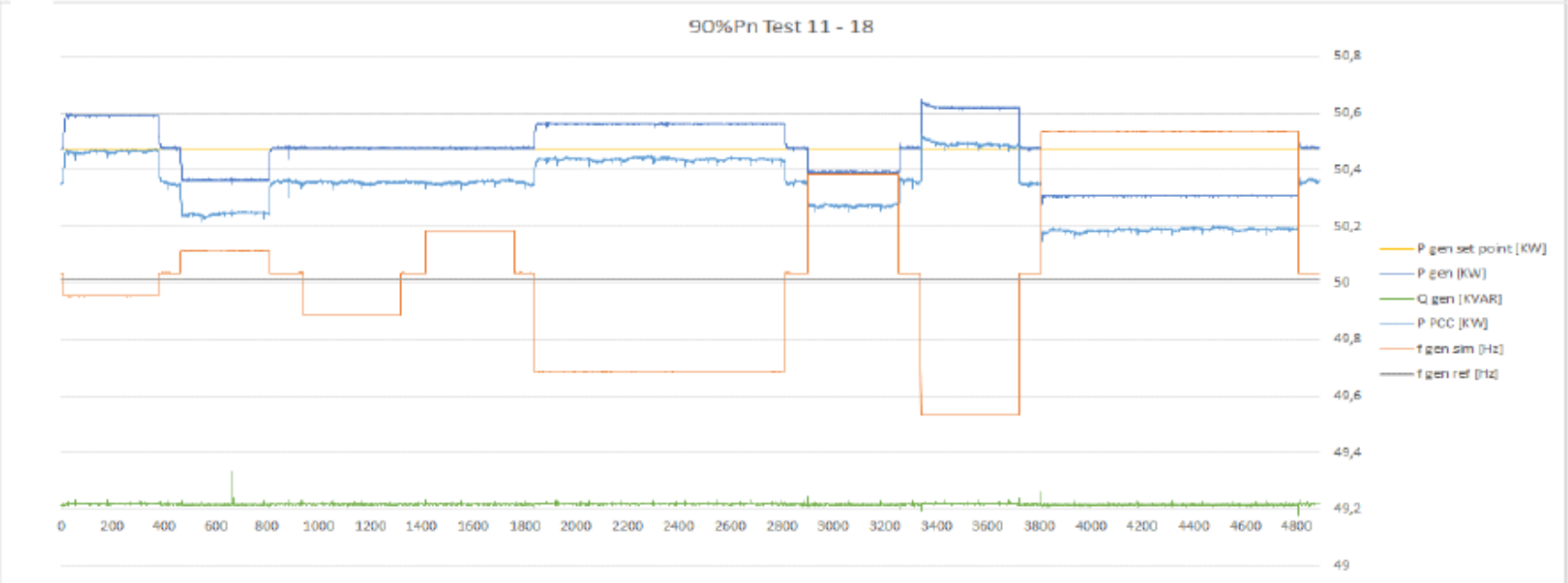


Generator active power and frequency reference when steps 19-22 are applied.

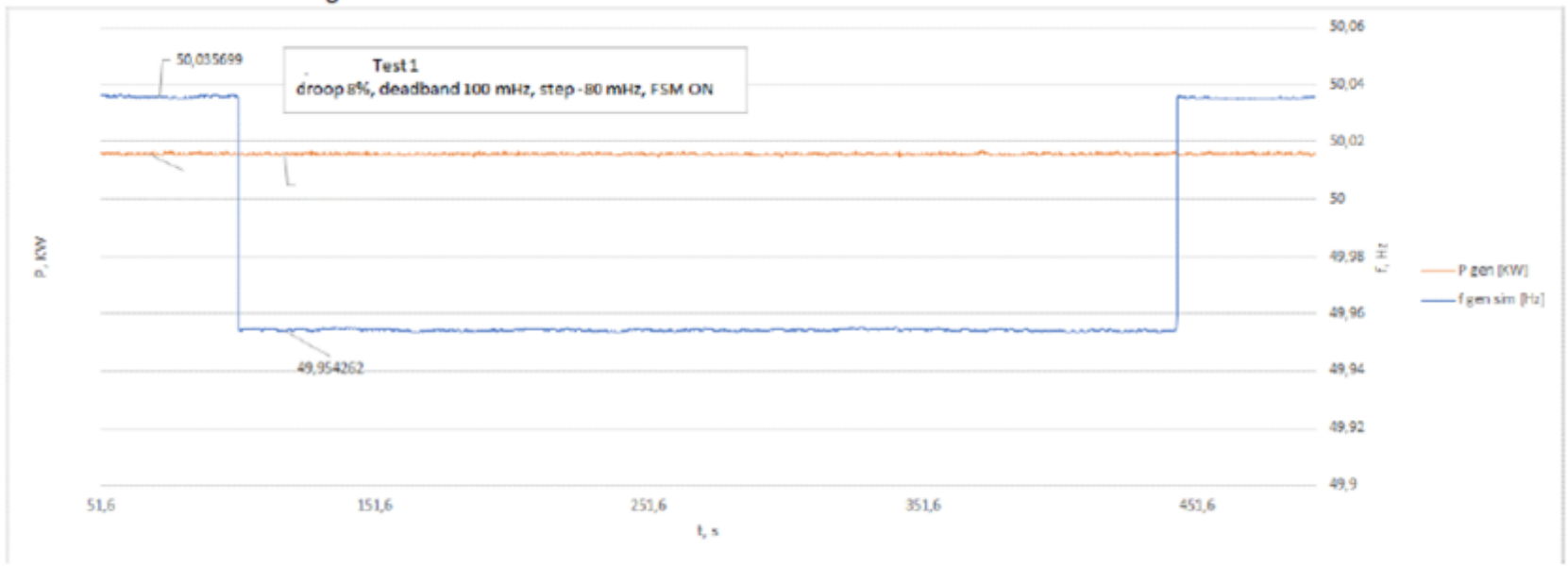
Second example :

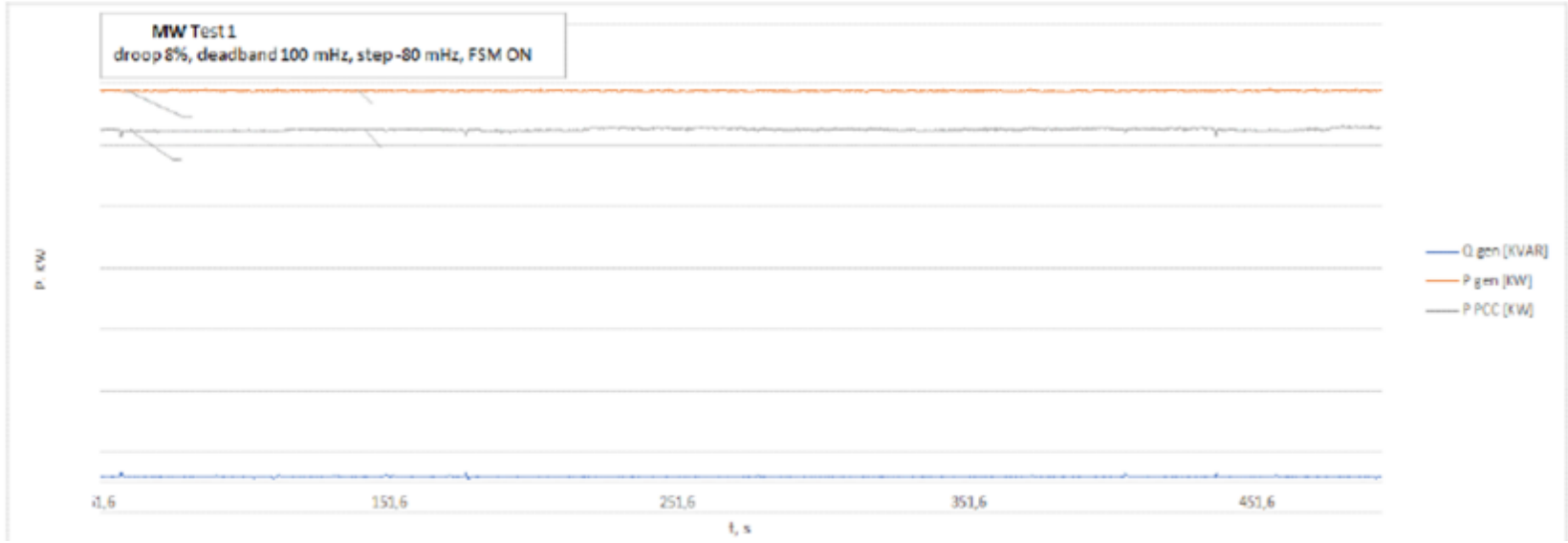
Changes applied		Test nr.	FSM Frequency control enabled	Droop (%)	Deadband (mHz)	Frequency step (mHz) (all changes from 50 Hz)	Power Setpoint MW 90% of Pn	Expected power change (MW)	Actual P change (MW) during test	P change (%)	Expected power (MW)	Actual deltaP (MW) during test	Minimum duration (after stabilized output), min.	Duration, min. during tests	Load change duration, s	±5% 50% reached, s (10 s)	±5% 100% reached, s (30 s)	Successful (YES/NO)
20:59:45	21:05:28	1	Yes	8	100	-80	X	0	X	0,0%	x	X	5	05:29	N/A	N/A	N/A	**YES**
21:06:58	21:12:47	2	Yes	8	100	80	X	0	X	0,0%	x	X	5	05:35	N/A	N/A	N/A	**YES**
21:14:10	21:20:17	3	Yes	8	100	-200	X	0,178	X	2,6%	x	X	5	05:27	7,4	2,8	7,4	**YES**
21:21:42	21:37:50	4	Yes	8	100	200	X	-0,178	X	-2,5%	X	X	15	15:22	6	2,4	6	**YES**
21:39:36	21:45:56	5	Yes	8	0	-80	X	0,142	X	2,0%	X	X	5	05:54	3,8	2,2	3,8	**YES**
21:47:19	21:53:15	6	Yes	8	0	80	X	-0,142	X	-2,0%	X	X	5	05:22	5,2	2,6	5,2	**YES**
21:54:52	22:00:36	7	Yes	2	100	-80	X	0	X	0,0%	X	X	5	05:28	N/A	N/A	N/A	**YES**
22:01:53	22:07:24	8	Yes	2	100	80	X	0	X	0,0%	X	X	5	05:20	N/A	N/A	N/A	**YES**
22:08:54	22:24:55	9	Yes	2	100	-200	X	0,71	X	9,9%	X	X	15	15:47	5,4	3,4	5,4	**YES**
22:26:20	22:32:21	10	Yes	2	100	200	X	-0,71	X	-9,8%	X	X	5	05:28	3,2	1,4	3,2	**YES**
22:43:45	22:50:10	11	Yes	2	0	-80	X	0,568	X	8,0%	X	X	5	05:20	9	3,4	9	**YES**
22:51:27	22:57:15	12	Yes	2	0	80	X	-0,568	X	-8,2%	X	X	5	05:24	4,4	1,6	4,4	**YES**
22:59:28	23:05:46	13	No	5	0	-150	X	0	X	0,0%	X	X	5	05:20	N/A	N/A	N/A	**YES**
23:07:23	23:13:06	14	No	5	0	150	X	0	X	0,0%	X	X	5	05:28	N/A	N/A	N/A	**YES**
23:14:26	23:30:49	15	No	5	0	-350	X	0,426	X	5,9%	X	X	15	15:21	9,2	1,2	9,2	**YES**
23:32:02	23:38:00	16	No	5	0	350	X	-0,426	X	-6,1%	X	X	5	05:20	3,4	0,7	0,8	**YES**
23:39:25	23:45:45	17	No	5	0	-500	X	0,71**	X	10,4%	x	X	5	05:32	46	1,2	1,4	**YES**
23:47:10	00:03:52	18	No	5	0	500	X	-0,852	X	-12,0%	X	X	15	15:29	0,8	0,7	0,8	**YES**

1.1.20. Recording: load generator MW

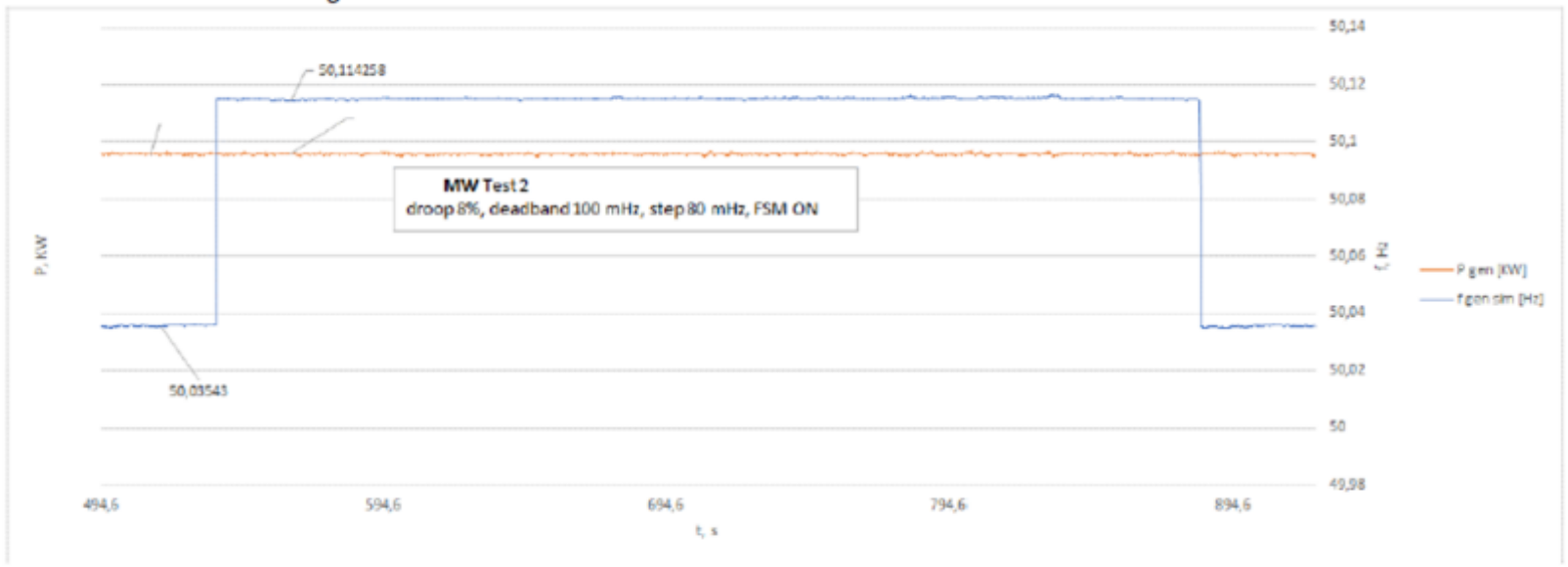


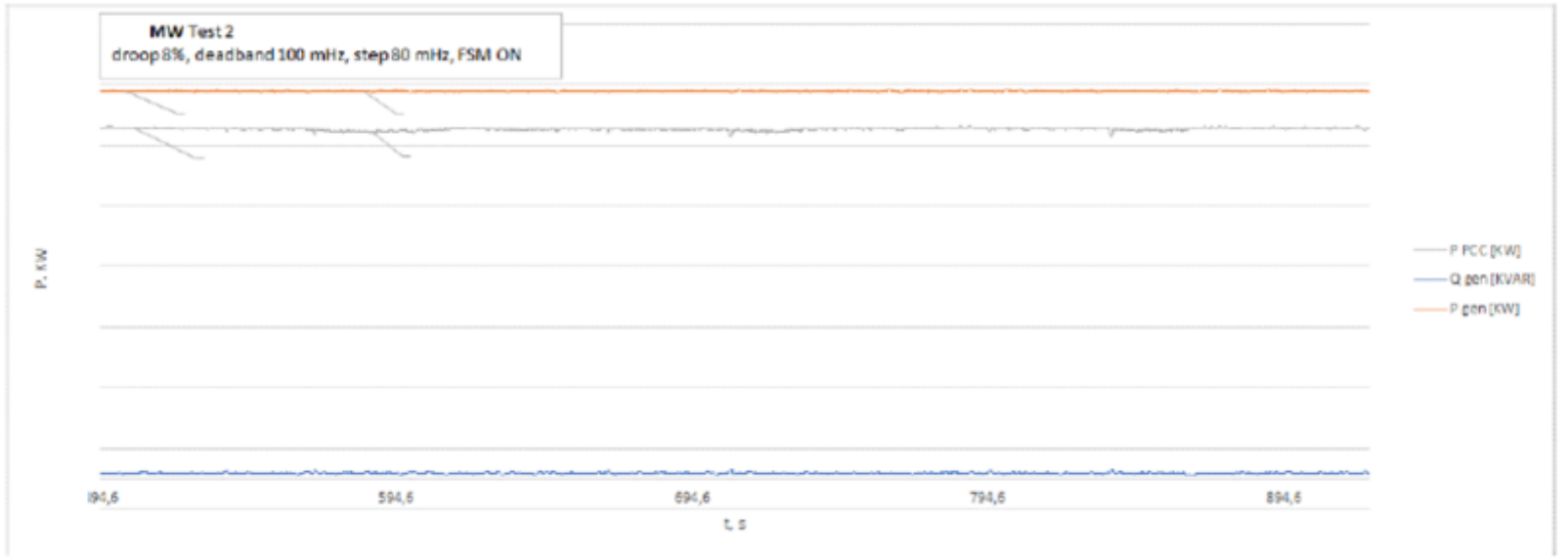
1.1.21. Record: load generator (MW Test 1



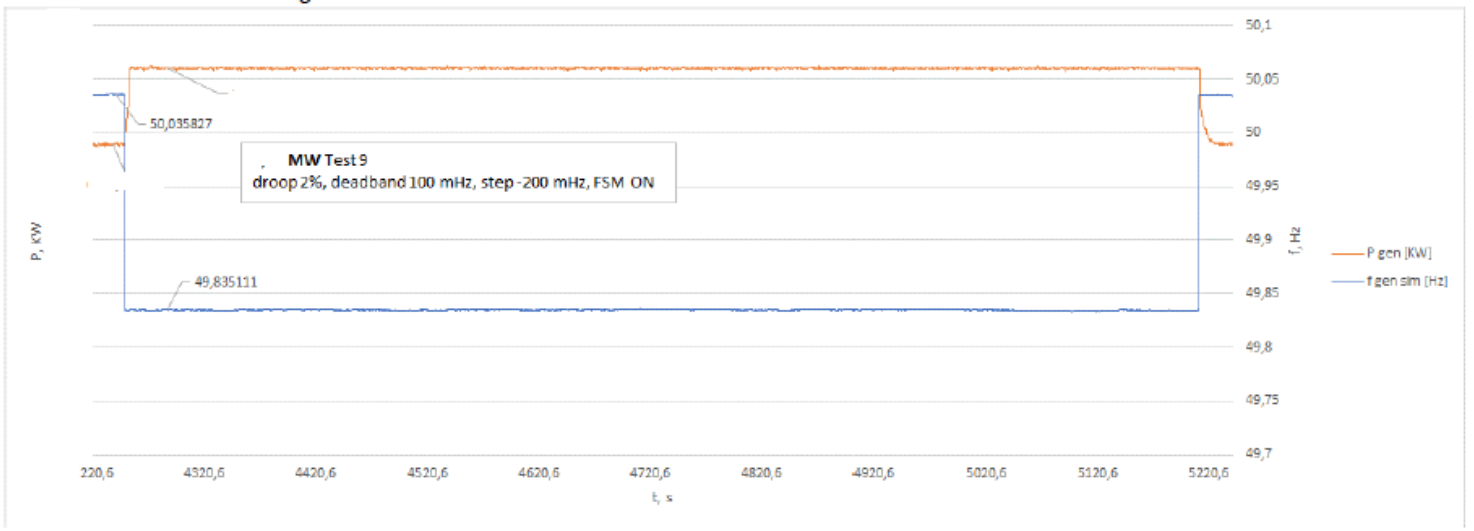


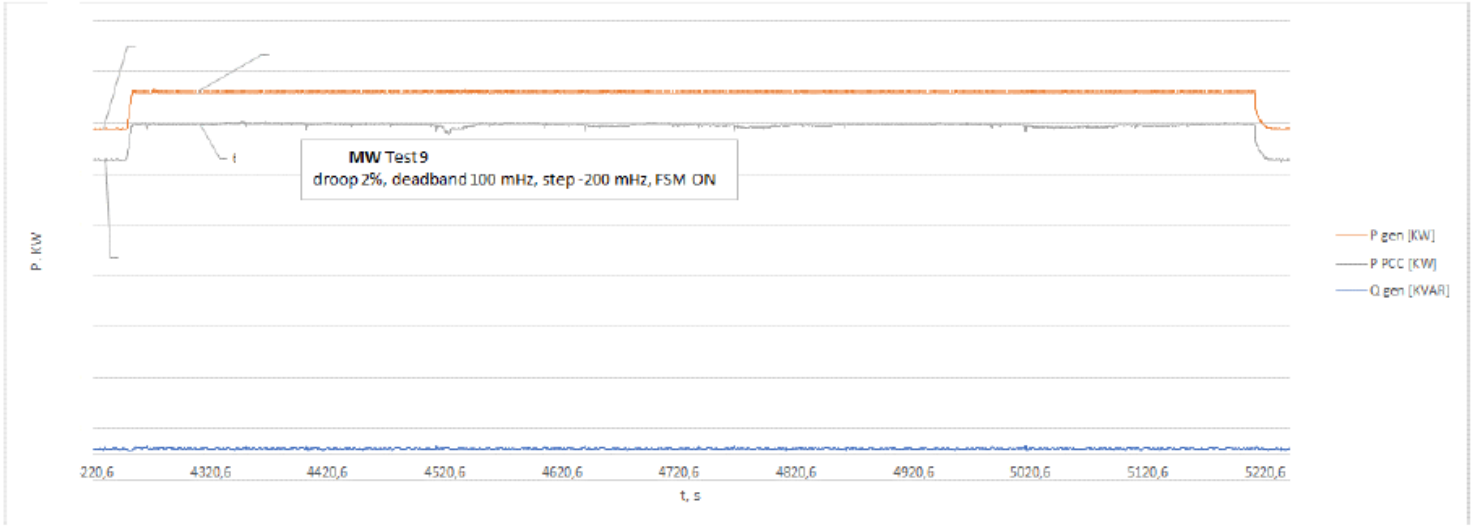
1.1.22. Record: load generator MW Test 2





1.1.29. Record: load generator MW Test 9





For every step same graphs to be shown.

TEST 11: Cold start to maximum rated power

Test conditions:

- This test was performed on XXX.
- This is a cold start of both boiler and turbine

Test execution:

Execution to cold mode:

- T0 => Stop feeding bio fuel to all 3 boilers
- T0 + 40mn => Stop steam turbine & By-pass turbine to DH network heat exchanger opened
- T0 + 5/6 h => “Feed chute hopper” and grates of 3 boilers emptying
- T0 + 6/7 h => Stop Primary & Secondary air, IDF at 5-10% load
- The Boiler will stay fully closed, primary and secondary air fans stopped, IDF can running at 5-10 % load. Burner off during 24 h

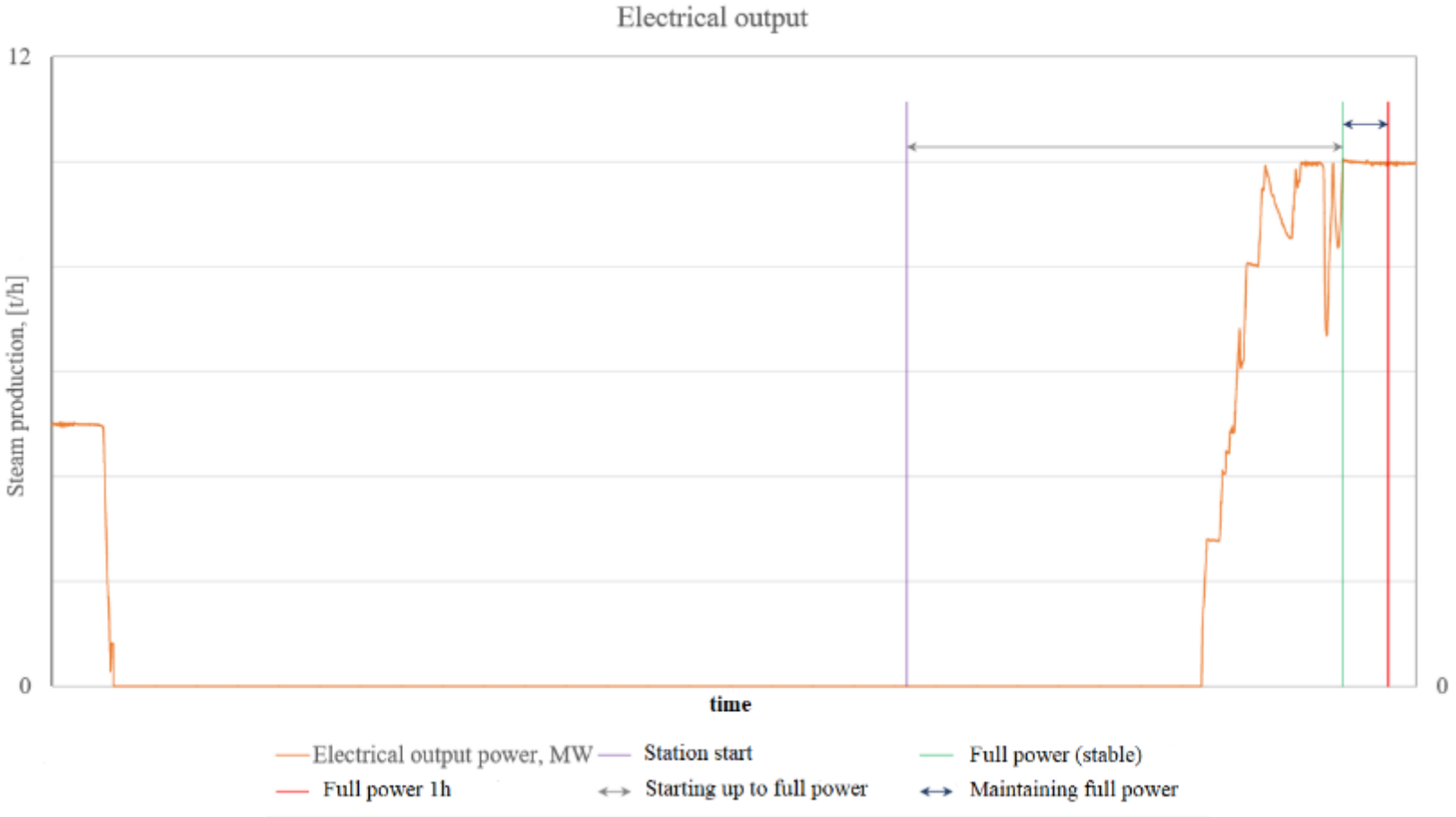
Execution to restart mode:

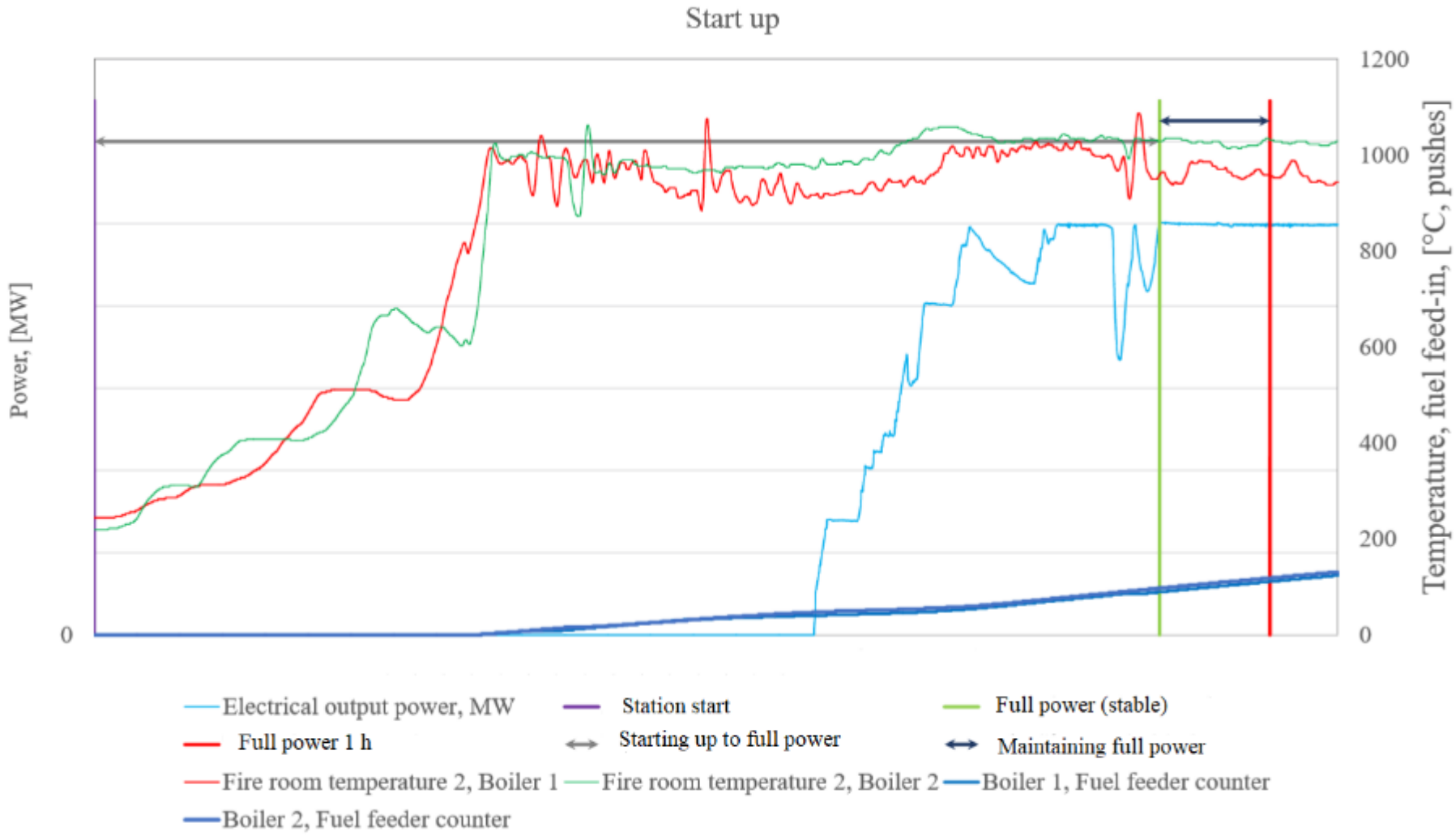
- T0 + 26h (Tcold) => Restart All fans (IDF, Primary, and Secondary) & Start burners of 3 boilers after scavenging (20mn)
- T0 + 27 h => Fill “feed chute hoppers” with wood chips introduction.
- T0 + 30/31h => Pre-heating steam pipes for admission turbine
- T0 +33/34h => Preparation to start steam turbine T0 + 35/36h (Tend) => Steam turbine on the network xMW

Success criteria:

- Tcold = T0 +26h, assuming boiler stop at T0 +2h.
- Steam turbine shall produce XX MW before Tend = Tcold + 12h during 1 hour. (Around T0 +38h)

Test results:




Start up
Power, [MW]
0
1200
1000
800
600
400
200
0
Temperature, fuel feed-in, [°C, pushes]
Electrical output power, MW
Station start
Full power (stable)
Full power 1 h
Starting up to full power
Maintaining full power
Fire room temperature 2, Boiler 1
Fire room temperature 2, Boiler 2
Boiler 1, Fuel feeder counter
Boiler 2, Fuel feeder counter