

ABB Oy Drives		ACS800 Island Converter		Island Converter Measurement Report.DOC	
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This is a report of ACS800 Island Converter on site measurements

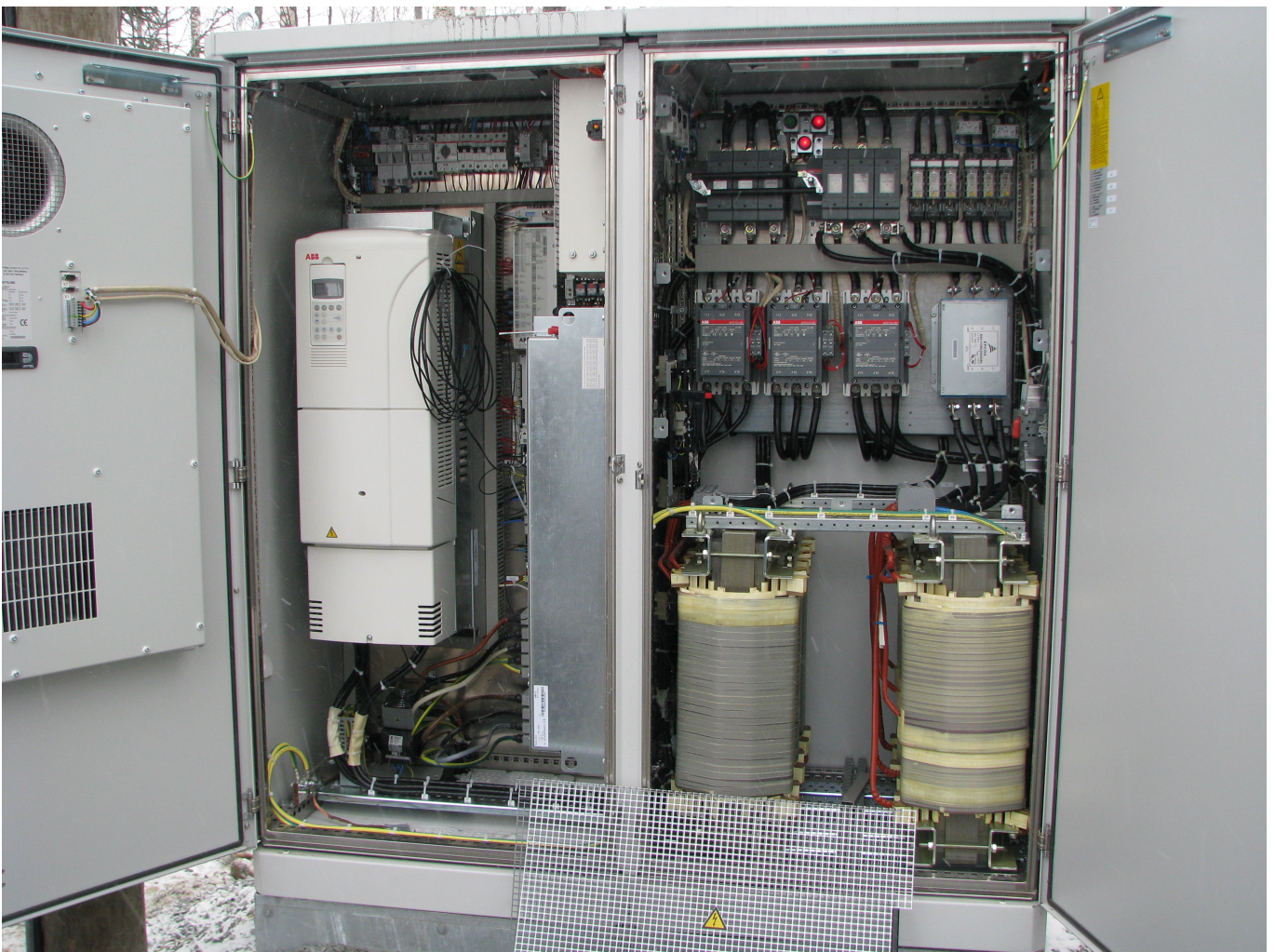


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1 Introduction

This is a report of field measurements of ACS800 Island Converter. The purpose of the converter is to improve the power quality in the end of weak distribution line. Measurements that were completed before the installation show high variation of distribution voltage due to long, weak distribution line and relatively high load. The consumers at the end of the distribution line had been complaining about dimming lights etc.

The purpose of these measurements was to verify correct operation of the island converter and to analyze the power quality in the island network.



Figure 1-1 Simple map of the summer cottage village.

The installation is in countryside in mid Finland (Figure 1-1). The power to the island converter is supplied through a 920 m low voltage distribution line. It consists of 620 m of AMKA50 and 300 m of AMC35 subsea cable (figure 1-2). Island converter creates separate 400/230V and 50 Hz island network for these summer cottages. The load in this island network is typical single phase household equipment: lights, radio, television, oven, sauna, water pump, electric saw etc.

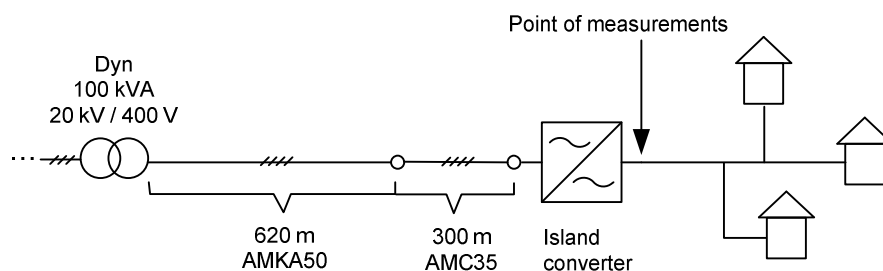


Figure 1-2 Single-line diagram of the distribution network.

The summer cottages are connected to the distribution network of Vattenfall Verkko Oy. The measurements were performed in cooperation with ABB Oy Drives and Vattenfall Verkko Oy. The whole cabinet consists of two power stages; one line converter as rectifier and the other one as island converter generating island network.

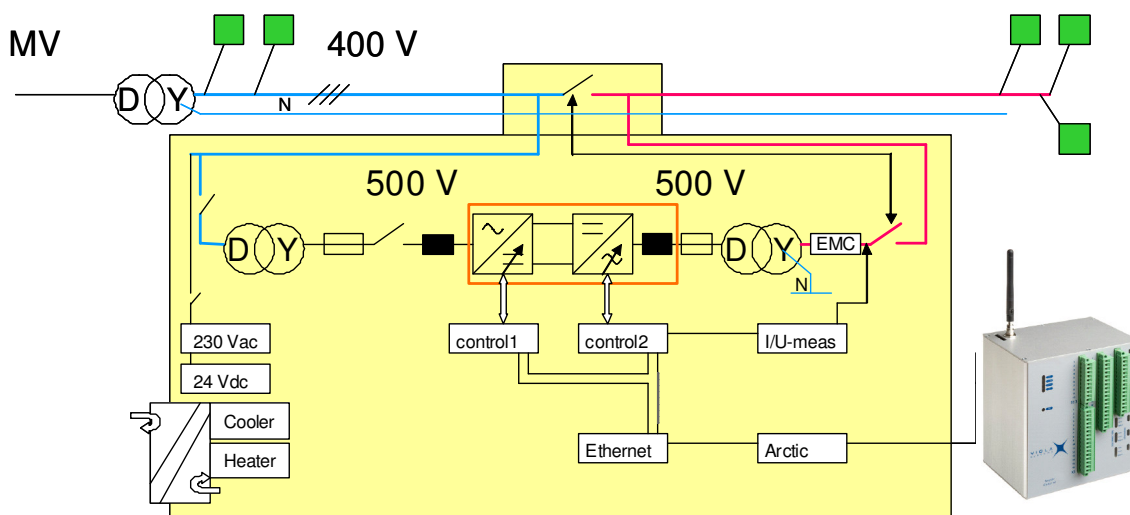


Figure 1-3 Simple block diagram of the converter cabinet.

2 Measurements

2.1 Measuring Equipment

HIOKI 8855 MEMORY HiCORDER (sampling period 20 μ s)

- voltage measurements with HIOKI probes: three line-to-ground voltages
- current measurements using Yokogawa 701930 Current probes

EURO-QUANT (EWS 130) (averaging period 1 min)

- three line-to-ground voltages
- three line current measurements with Rogowsky coils

EURO-QUANT was programmed to measure rms voltages and currents, active and reactive power, harmonics, flicker, etc. HIOKI was used to store instantaneous voltages and currents. EURO-QUANT stored the average, maximum and minimum values of the stored quantities during 1 minute periods.

2.2 Measurement Schedule

<i>Time</i>	<i>Event</i>
- 12:30	<i>Power on, original network connected to island.</i>
13:20	<i>Island converter start-up</i>
13:35	<i>Fixing the measurement set-up</i>
14:50	First summer cottage power switched on - Heat pump on
14:55	Second summer cottage main switch on
14:58	Third summer cottage main switch on
15:01	Island converter parameter adjustment - Compensation of harmonics 3.pos, 5.neg, and 7.pos on
15:19	Active loads: heat pump
15:21	Active loads: heat pump, oven
15:23	Active loads: heat pump, and sauna
15:26	Active loads: heat pump, and electrical saw
15:27	Active loads: heat pump, and electrical saw
15:40	End of measurements

2.3 Voltage, current, power

The following figures present measurement results of time period 14:35 - 15:35.

Figure 2-1 shows that despite of high and unbalanced load, the voltages stays nominal.

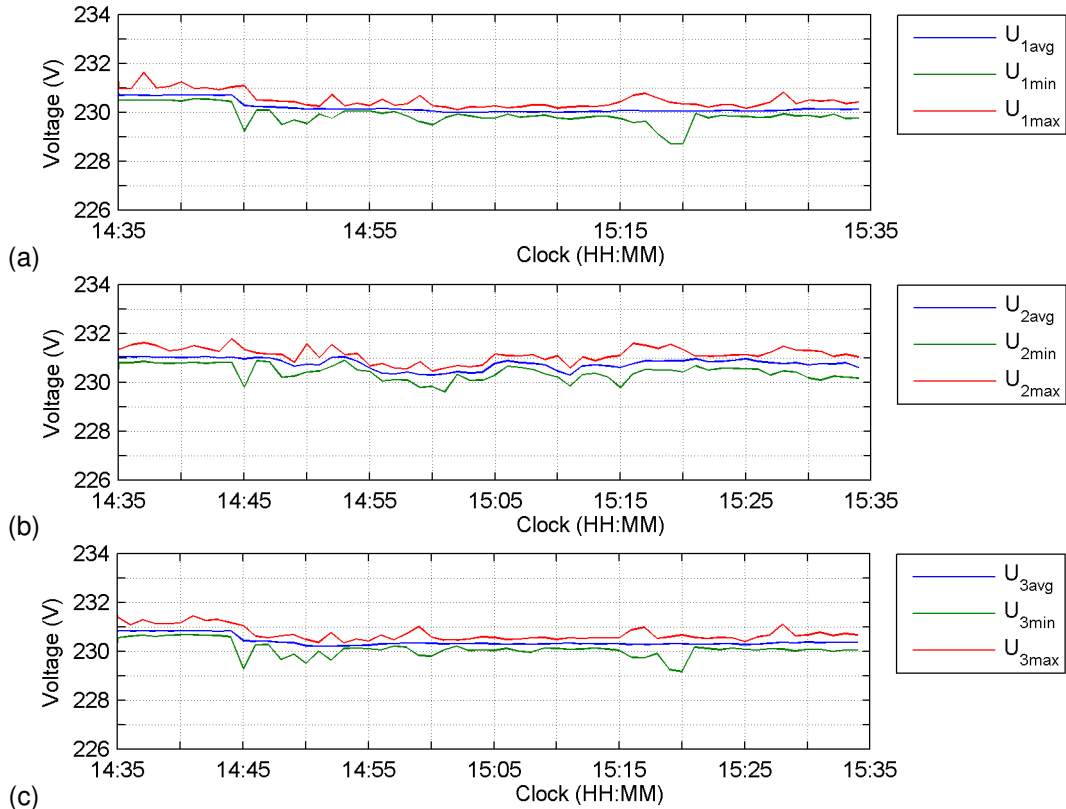
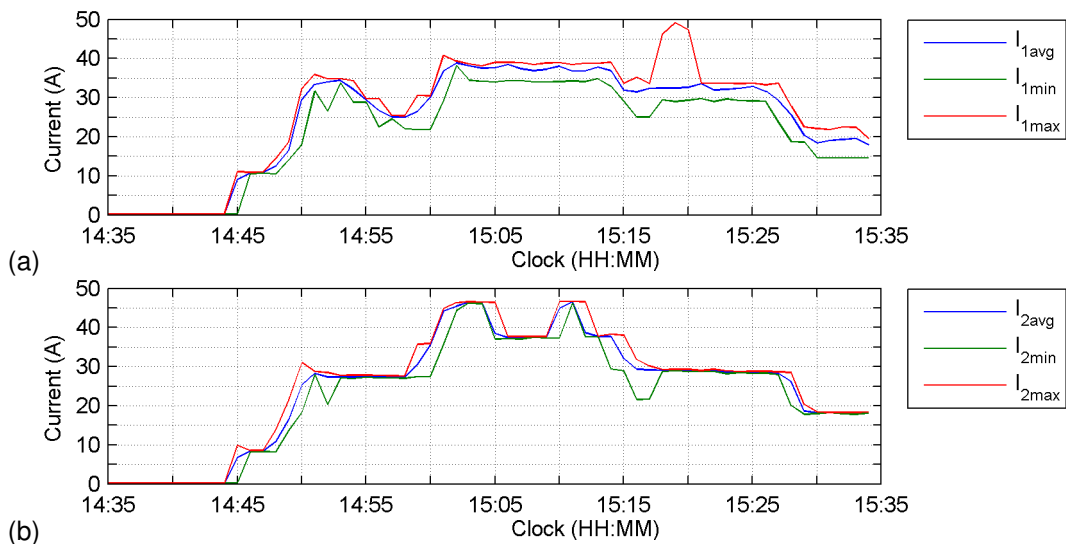
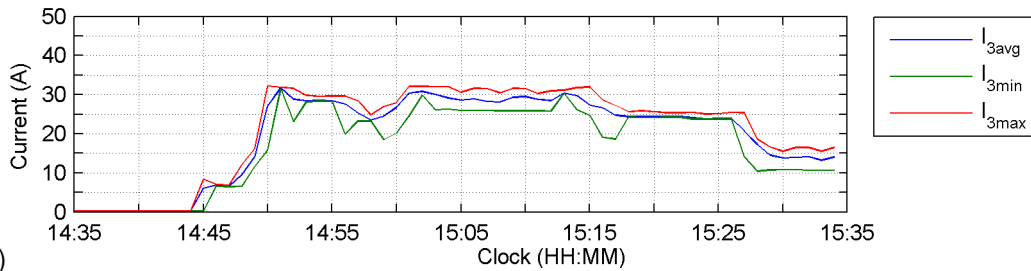


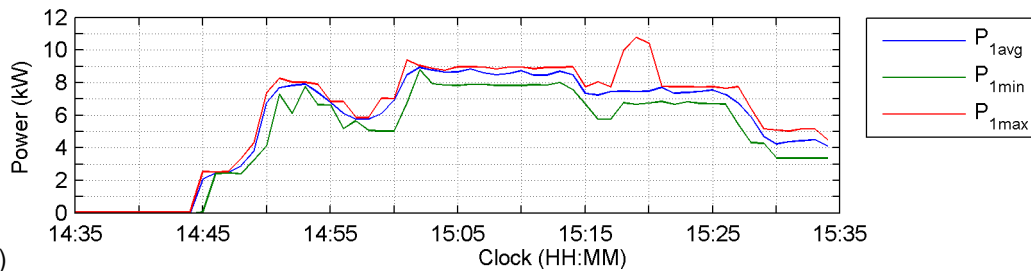
Figure 2-1 Island network line-to-neutral rms voltages; average, minimum, and maximum value during one minute sampling time.



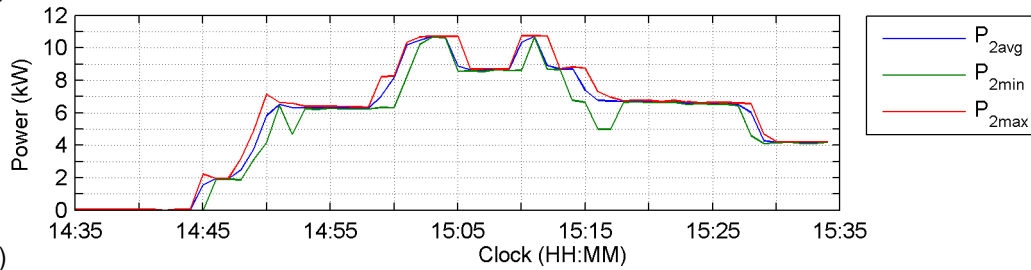


(c)

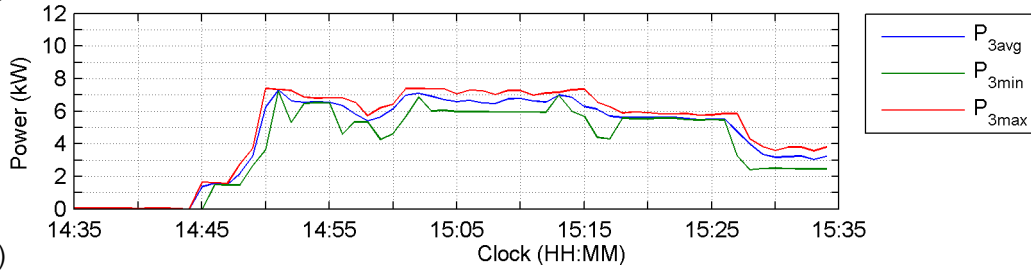
Figure 2-2 Island network line currents, average, minimum, and maximum values during one minute sampling period.



(a)

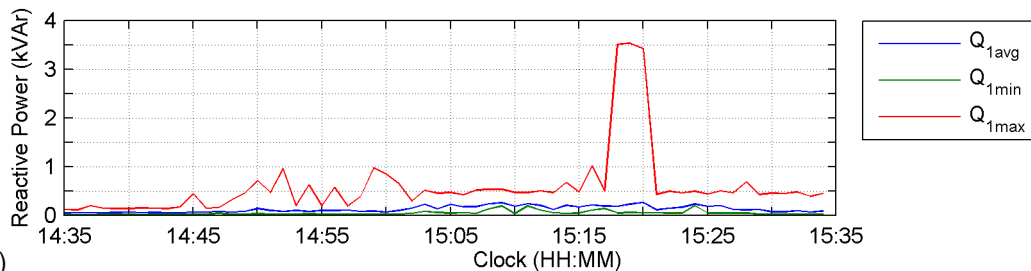


(b)

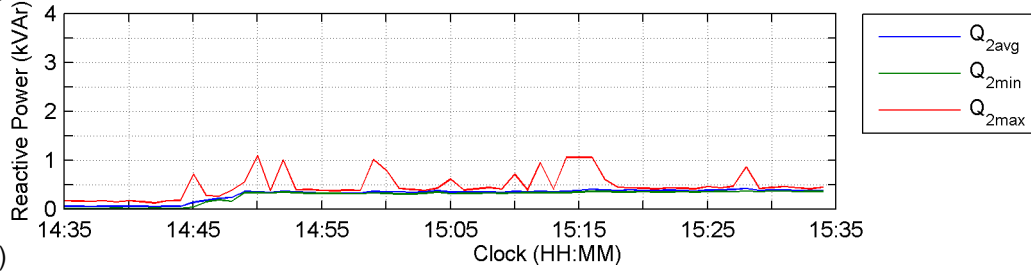


(c)

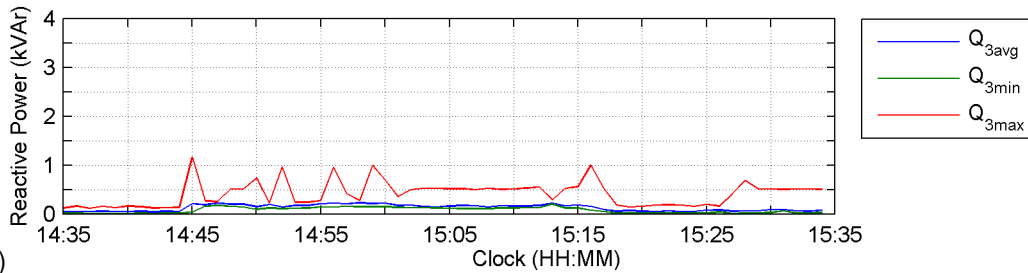
Figure 2-3 Island network active power (each phase), average, minimum, and maximum values during one minute sampling period.



(a)



(b)



(c) **Figure 2-4 Island network reactive power (each phase), average, minimum, and maximum values during one minute sampling.**

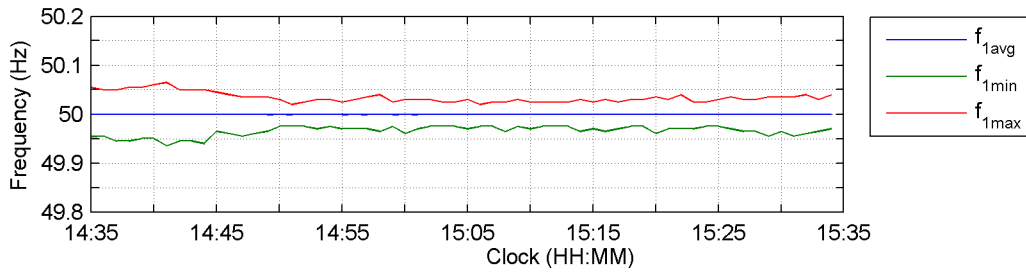
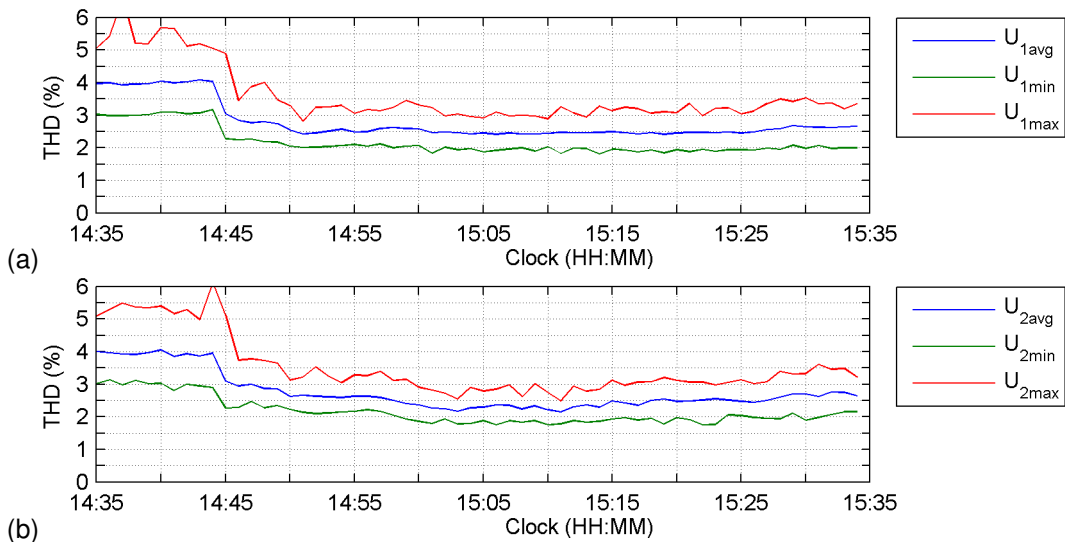
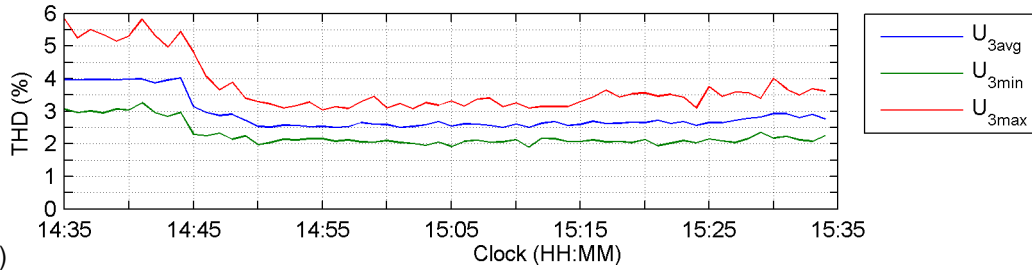


Figure 2-5 Island network frequency, average, minimum, and maximum values during one minute sampling.

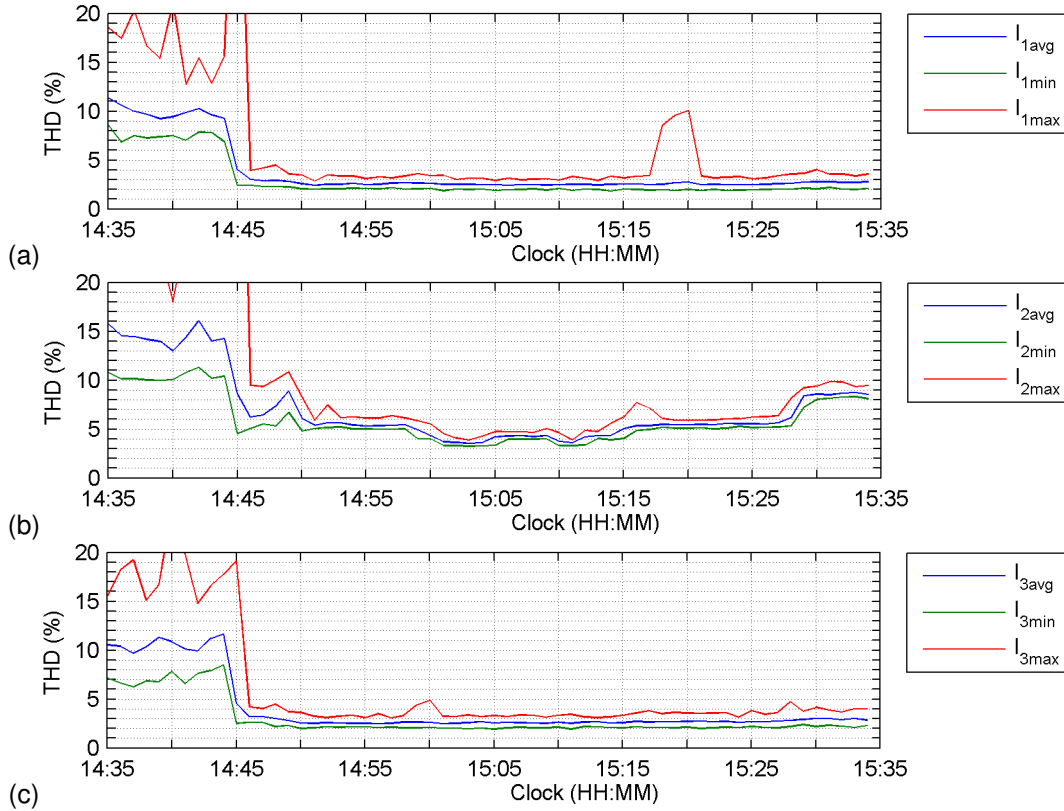
2.4 Voltage distortion

Connection of single phase loads started at 14:45. Figures 2-6 and 2-7 show that distorted load current does not cause distortion in voltage. When loaded, the voltage THD is less than 3%. Effect of compensation of harmonic voltages can be seen in figures 2-9 and 2-10. However, the effect on voltage THD is small. Figure 2-8 shows typical spectrum of interharmonics of DTC controlled line converter. Figure 2-11 presents line-to-neutral voltage FFT sums. There are no resonance points in frequency range 2.5 – 9 kHz.





(c) **Figure 2-6 Total harmonic distortion THDU of phase-to-neutral voltages, average, minimum, and maximum values during one minute sampling period.**



(a) (b) (c) **Figure 2-7 Total harmonic distortion THDI of line currents, their average, minimum, and maximum values during one minute sampling period.**

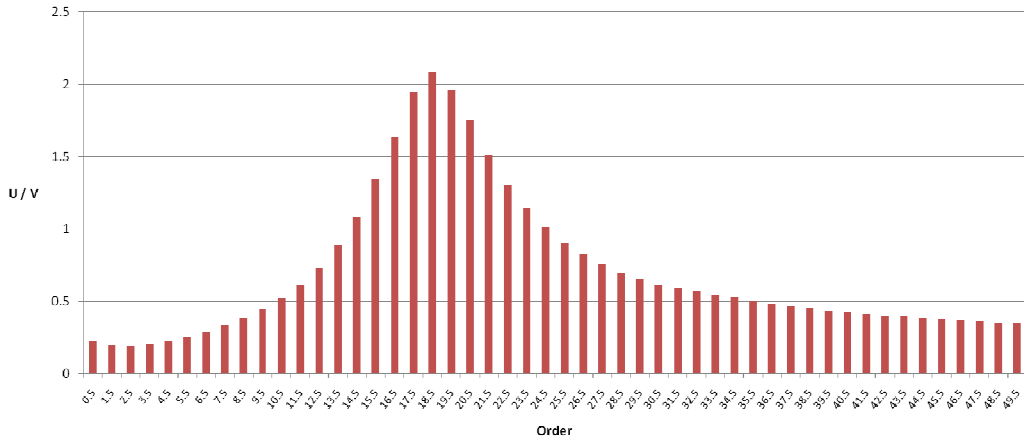


Figure 2-8 Time 15:05. Line to neutral interharmonic voltages. Power is about 25 kW.

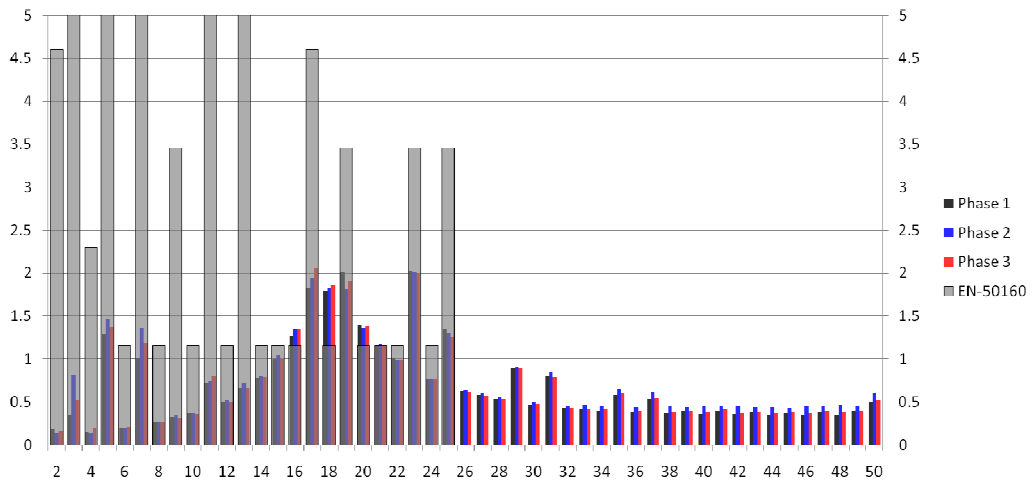


Figure 2-9 Time 14:45 – 14:55. 10 minute average of harmonic voltages. Compensation of harmonics 3.pos, 5.neg, and 7.pos is OFF. Power is about nominal 25 kW.

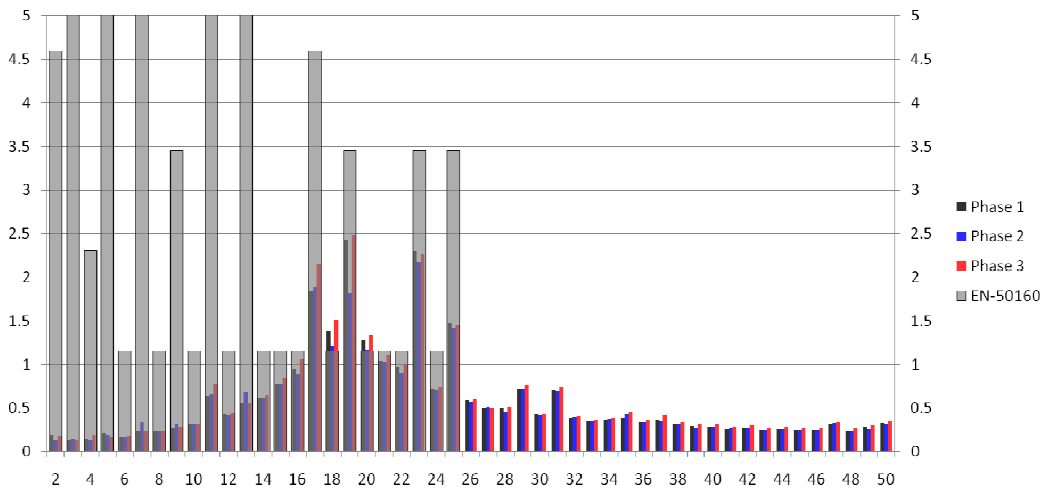


Figure 2-10 Time 15:01 – 15:11. 10 minute average of harmonic voltages. Compensation of harmonics 3.pos, 5.neg, and 7.pos is ON. Power is about nominal 25 kW.

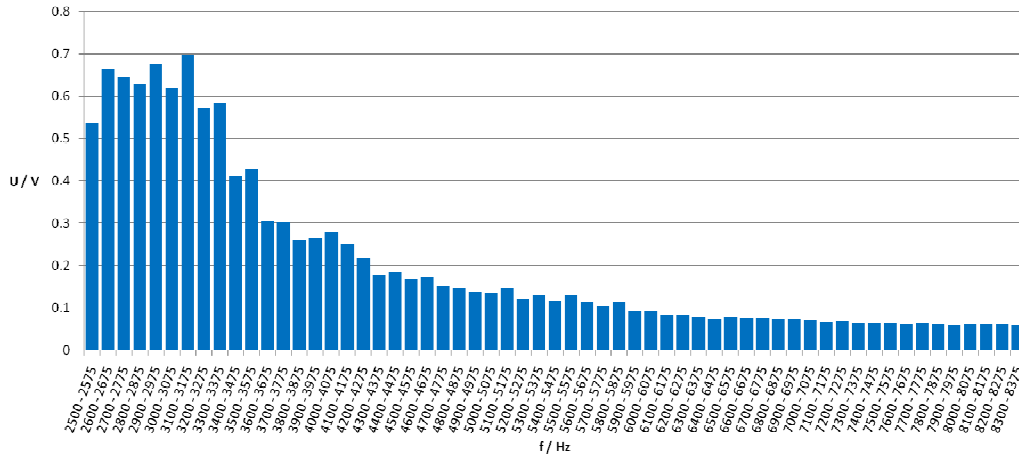


Figure 2-11 Time 15:05. Line to neutral voltage FFT sums 2.5 -9 kHz. FFT-sum window is 75 Hz. Power is about 25 kW.

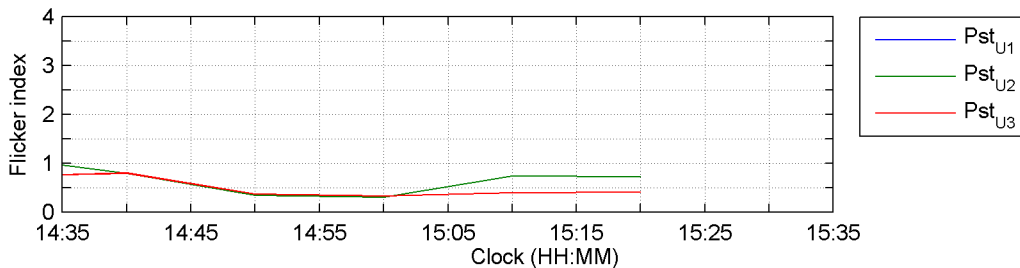


Figure 2-12 Short-term flicker of three line-to-neutral voltages.

Loading change starts after 15:00. That causes slight rise in flicker, but it is still well below 1.

2.5 Instantaneous voltages

Following figures are recordings of instantaneous line-to-neutral measurements. Figures 2-14 – 2-16 show that load changes affect slightly on instantaneous values of line-to-neutral voltages.

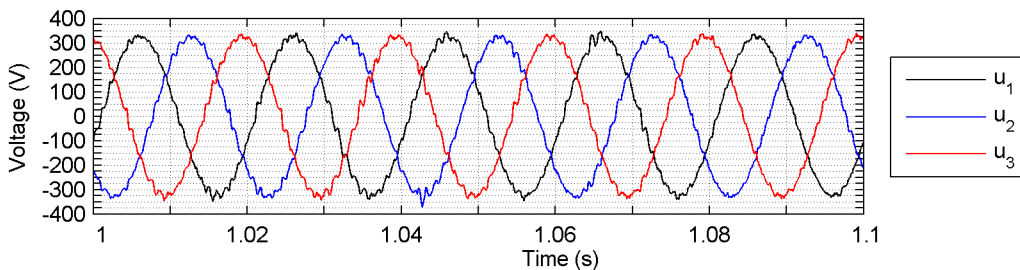


Figure 2-13 Instantaneous phase-to-neutral voltages.

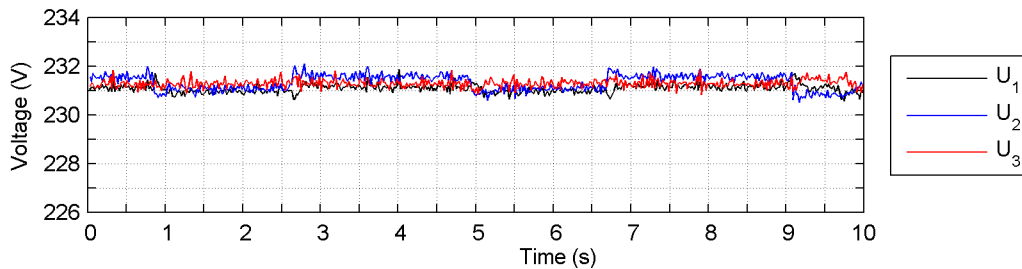


Figure 2-14 Time 15:22. Oven is switched on and off several times. Rms line-to-neutral voltages

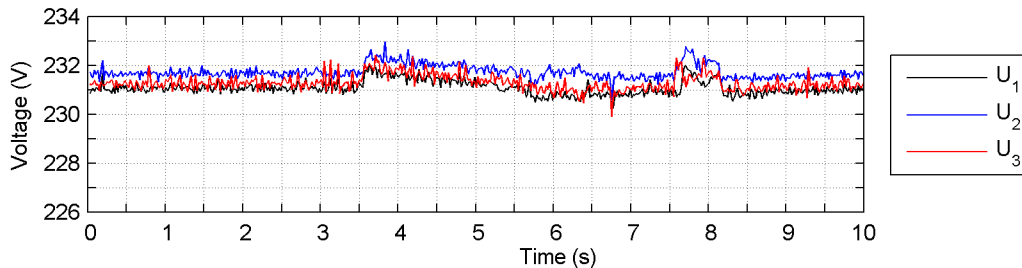


Figure 2-15 Time 15:23. Sauna is switched off and on. Rms line-to-neutral voltages measured

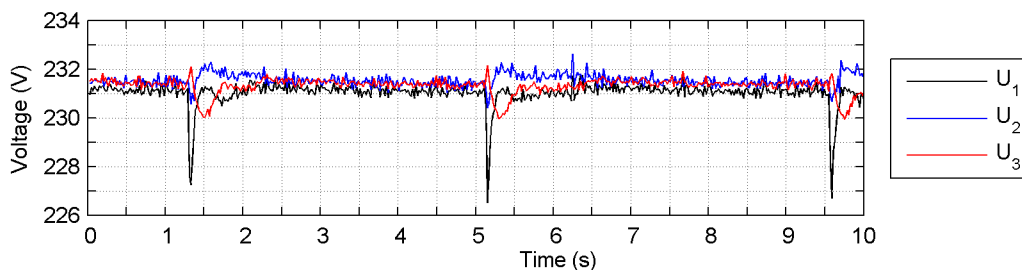


Figure 2-16 Time 15:27. Several starts with electric disc saw. Rms line-to-neutral voltages.

2.6 Impacts on supplying network

Figures 2-17 – 2-23 present EuroQuant measurements in time period 14:35 – 15:35. Only one phase in supply network could be measured together with island network measurements. Thus, the results should be considered only indicative. The measurements show that supplying network is weak and voltage variation is highly depending on the island network load. Lowest recorded input voltage level was 170 V, whereas the nominal voltage is 230 V.

Figure 2-20 shows that reactive power from supply network is almost zero due to active rectifier. The reactive power consumed in the island network is not transferred to the supply network.

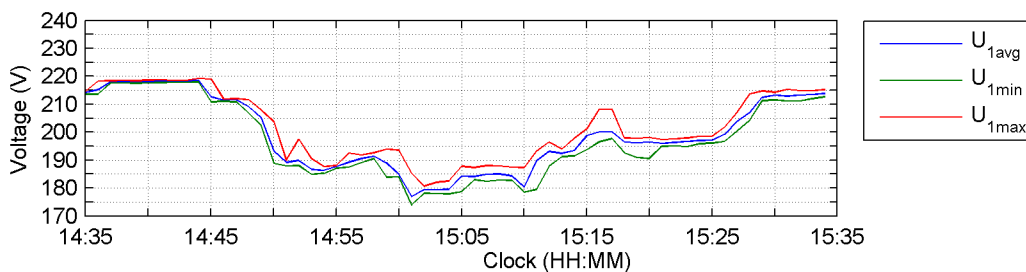


Figure 2-17 Supply network L1 line-to-neutral rms, its average, minimum, and maximum values during one minute sampling period.

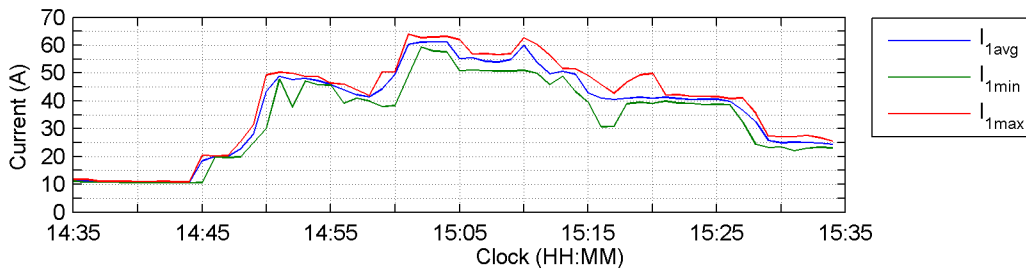


Figure 2-18 Supply network L1 line current, its average, minimum, and maximum values during one minute sampling period.

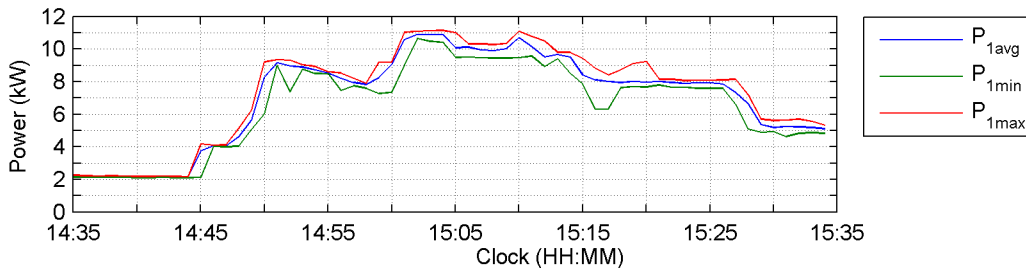


Figure 2-19 Supply network L1 active power, its average, minimum, and maximum values during one minute sampling period.

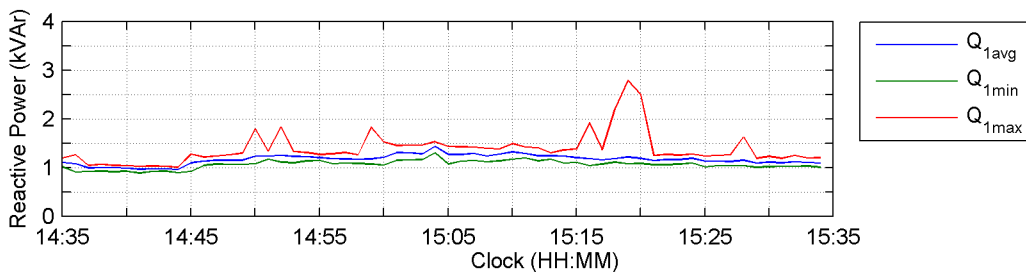


Figure 2-20 Supply network L1 reactive power, its average, minimum, and maximum values during one minute sampling.

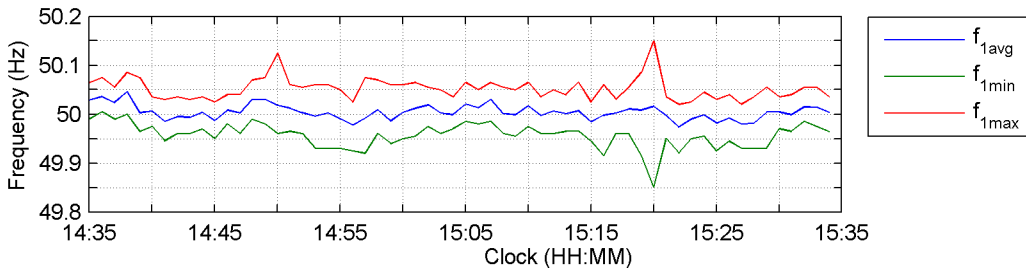


Figure 2-21 Supply network frequency, its average, minimum, and maximum values during one minute sampling.

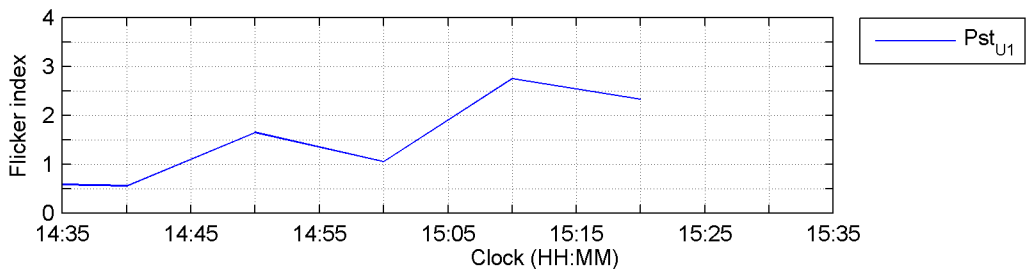


Figure 2-22 Supply network L1 line-to-ground short-term flicker (10 minutes).

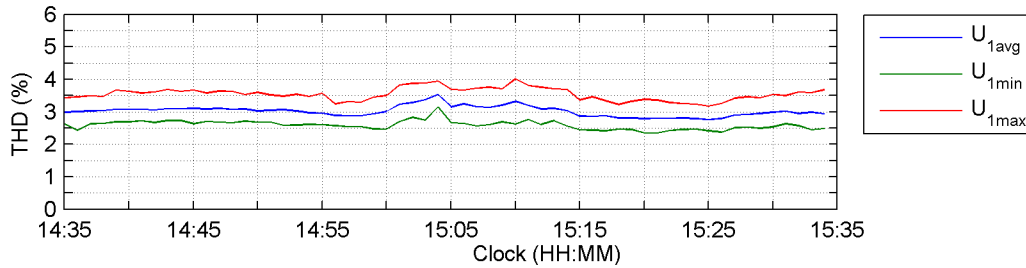


Figure 2-23 Supply network Total Harmonic Distortion THDU of line-to-neutral voltage, its average, minimum, and maximum values during one minute sampling period.

3 Follow up of converter

The status of the converter was checked on 21.05.2010. It had been running since commissioning in March without any trippings. There had been several short time outages (maybe autoreclosing 0.5 s) in the supply network, but they had not caused converter trip. Usually thunder and lightning generate this kind of outages. Although outages in the supply network, there was no outage in the island network. The capacitors in the DC-link were sufficient to keep the island converter running during these supply network incidents.

The energy consumption of the supply converter and island converter was checked at the same time. Measured energy during time period 17.03 – 21.05.2010 was 3.2 MWh on supply side and 1.8 MWh on island side. Average power of island network was 1.2 kW and average losses of the whole cabinet were less than 0.9 kW.

The consumers in this small village have been very satisfied with the power quality. The only complaint is dealing with the audible noise. The audible noise is coming from the cooling system of the converter cabinet. The measurements of audible noise and action plan how to limit the noise is now in the process.

4 Conclusions

The original complaint from consumers was voltage variation exceeding the limits in standard EN-50160. This document reports power quality measurements made in island network generated with ACS800 Island Converter in real environment. Measurement results show that all three line-to-neutral voltages are maintained between 228 V and 232 V, although the single phase load in the network varies from zero to 50 A. The voltage variation was less than 2%, the voltages were balanced and short term flicker index (Pst) was less than 1. It can be concluded that the island converter corrected the power quality and the requirements in standard EN-50160 are fulfilled.

Total harmonic distortion THDU of phase-to-neutral voltage presented in this document was in the range of 3%. However, it should be noted that harmonics of orders 18 and 20 exceeded the limits defined in standard EN-50160. The converter compensated the selected low order harmonics and asymmetry caused by load. The spectrum of voltage distortion in frequency range 0 – 2 kHz is typical to used modulation method and line filter.

There was no indication of network resonance in frequency range 2.5 – 9 kHz.

The power quality measurements show that power quality in this island network is improved. The converter takes the needed power from the supply network. However, this leads to losses and voltage variations in the supply network. The consumers in the start point of the distribution line may now suffer from voltage variations.

The benefits on the supply network are: the reactive power is zero, single phase and distorting load is now limited to the island network only. They do not load nor distort the supplying distribution line. The supply side converter keeps the supply current symmetrical, distortion low and $\cos\phi$ as 1.

In this experiment, the distribution line was cut and the island converter fed network was installed in the end of the distribution line. A better solution could be installing the rectifier part in the beginning on the distribution line, transfer all power through this 920 m DC-cable and keep the island converter where it is now.

From the technology perspective, the island converter was a success. It solved the problem in which it was designed for.

5 Appendixes

Table 5-1 Island network harmonics

Harmonic order	14:45 - 14:55 3.pos, 5.neg, and 7.pos compensation off			15:01 - 15:11 3.pos, 5.neg, and 7.pos compensation on			EN-50160 requirement for 230 V phase voltage
	U1	U2	U3	U1	U2	U3	
2	0.18	0.14	0.16	0.20	0.12	0.19	4.60
3	0.35	0.81	0.52	0.13	0.15	0.13	11.50
4	0.15	0.15	0.19	0.14	0.14	0.20	2.30
5	1.29	1.47	1.37	0.21	0.20	0.16	13.80
6	0.19	0.19	0.20	0.17	0.17	0.18	1.15
7	1.01	1.37	1.18	0.24	0.34	0.24	11.50
8	0.26	0.27	0.26	0.23	0.23	0.23	1.15
9	0.32	0.34	0.31	0.27	0.32	0.28	3.45
10	0.37	0.37	0.36	0.32	0.31	0.31	1.15
11	0.72	0.75	0.80	0.64	0.66	0.77	8.05
12	0.51	0.52	0.51	0.43	0.42	0.44	1.15
13	0.65	0.73	0.66	0.57	0.68	0.56	6.90
14	0.77	0.80	0.78	0.62	0.62	0.65	1.15
15	1.00	1.04	1.00	0.77	0.77	0.84	1.15
16	1.27	1.34	1.35	0.96	0.89	1.06	1.15
17	1.83	1.93	2.06	1.85	1.89	2.16	4.60
18	1.79	1.82	1.87	1.38	1.21	1.51	1.15
19	2.01	1.81	1.91	2.43	1.81	2.48	3.45
20	1.40	1.36	1.38	1.28	1.17	1.34	1.15
21	1.17	1.17	1.17	1.04	1.03	1.11	1.15
22	1.01	0.99	0.99	0.97	0.91	1.01	1.15
23	2.03	2.01	2.00	2.30	2.17	2.27	3.45
24	0.76	0.76	0.77	0.73	0.71	0.75	1.15
25	1.34	1.31	1.25	1.48	1.42	1.46	3.45
26	0.63	0.64	0.63	0.59	0.57	0.60	-
27	0.57	0.60	0.57	0.49	0.51	0.50	-
28	0.53	0.56	0.54	0.50	0.46	0.50	-
29	0.89	0.91	0.89	0.72	0.72	0.77	-
30	0.46	0.50	0.47	0.43	0.42	0.44	-
31	0.81	0.85	0.78	0.70	0.69	0.74	-
32	0.42	0.46	0.43	0.39	0.40	0.41	-
33	0.42	0.46	0.41	0.36	0.36	0.36	-
34	0.40	0.45	0.42	0.36	0.37	0.39	-
35	0.57	0.65	0.61	0.39	0.43	0.46	-
36	0.38	0.44	0.40	0.33	0.34	0.37	-
37	0.53	0.61	0.54	0.36	0.35	0.41	-
38	0.37	0.45	0.39	0.31	0.32	0.33	-
39	0.40	0.44	0.40	0.29	0.28	0.31	-
40	0.36	0.45	0.39	0.29	0.29	0.32	-
41	0.40	0.45	0.41	0.26	0.27	0.29	-
42	0.36	0.45	0.37	0.27	0.27	0.30	-
43	0.38	0.44	0.38	0.26	0.25	0.28	-
44	0.35	0.44	0.38	0.26	0.26	0.29	-
45	0.38	0.42	0.38	0.25	0.25	0.28	-
46	0.35	0.45	0.37	0.25	0.25	0.28	-
47	0.38	0.45	0.40	0.31	0.32	0.33	-
48	0.35	0.46	0.39	0.24	0.23	0.27	-
49	0.39	0.45	0.40	0.29	0.26	0.30	-
50	0.49	0.60	0.52	0.32	0.31	0.36	-

Table 5-2 Cumulative and average signals on 21.05.2010

	Commissioning		Shutdown		Difference		
	Grid	Island	Grid	Island	Grid	Island	
Total energy	10315	4181	13504	6013	3189	1832	kWh
Time of usaga	844	340	2373	1869	1529	1529	h
Average power	-	-	-	-	2.09	1.20	kW
Total losses	-	-	-	-	1356		kWh
Average losses	-	-	-	-	0.887		kW
ACS800 Temp	29.9	30.9	40.0	41.3	-	-	C
Power	8.11	5.75	3.47	2.17	-	-	kW
Reactive power	3.06	0.00	3.02	0.00	-	-	kVAr

The usage time is the same in both converters after they were commissioned. The power consumption in the island network was 1832 kWh during the period of time. The losses are quite high, but the intention of this experiment was not to optimize the losses but to prove the usability of this kind of technology.