

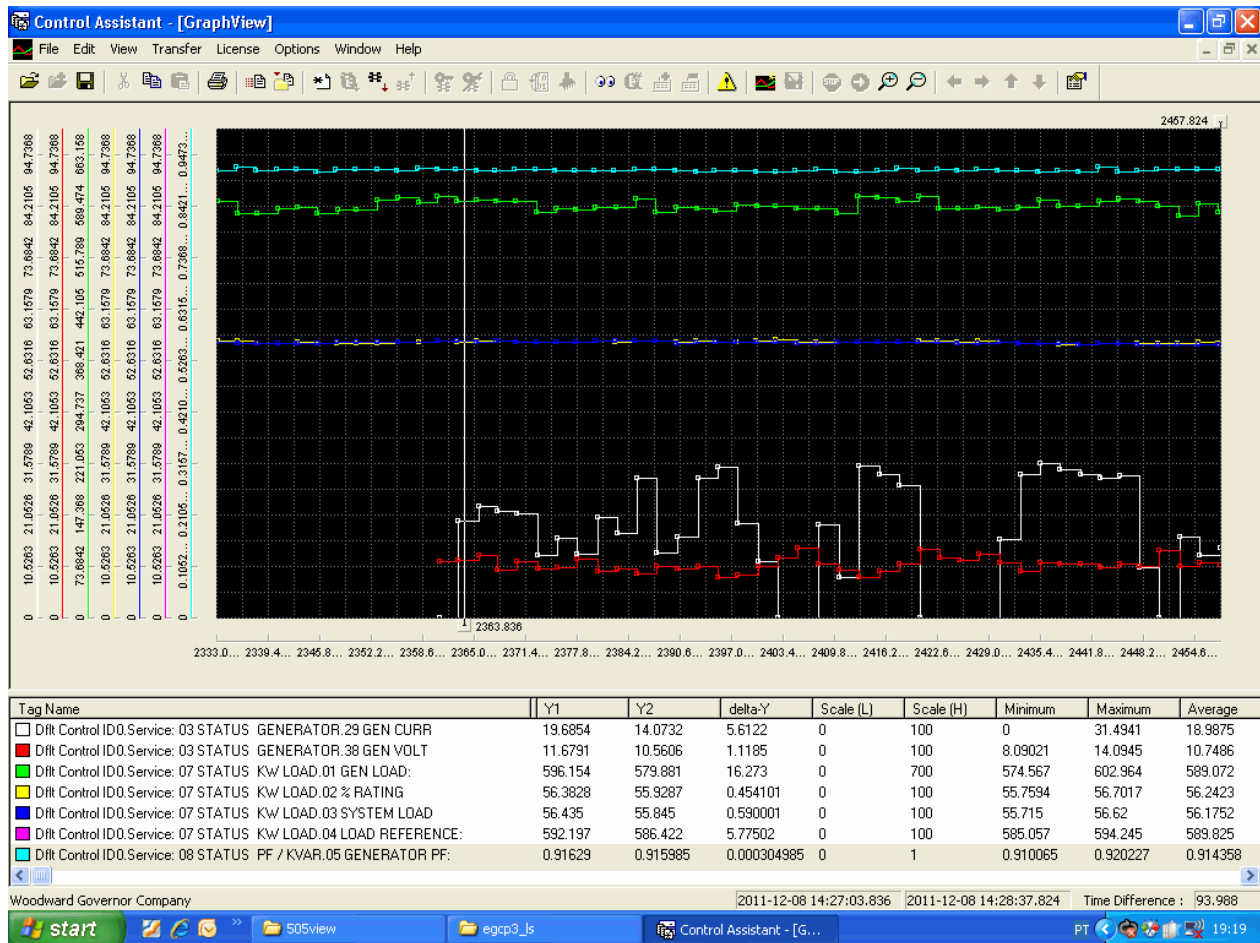
Harmonic Stress Test

easYgen3500 TL: 8440-3934

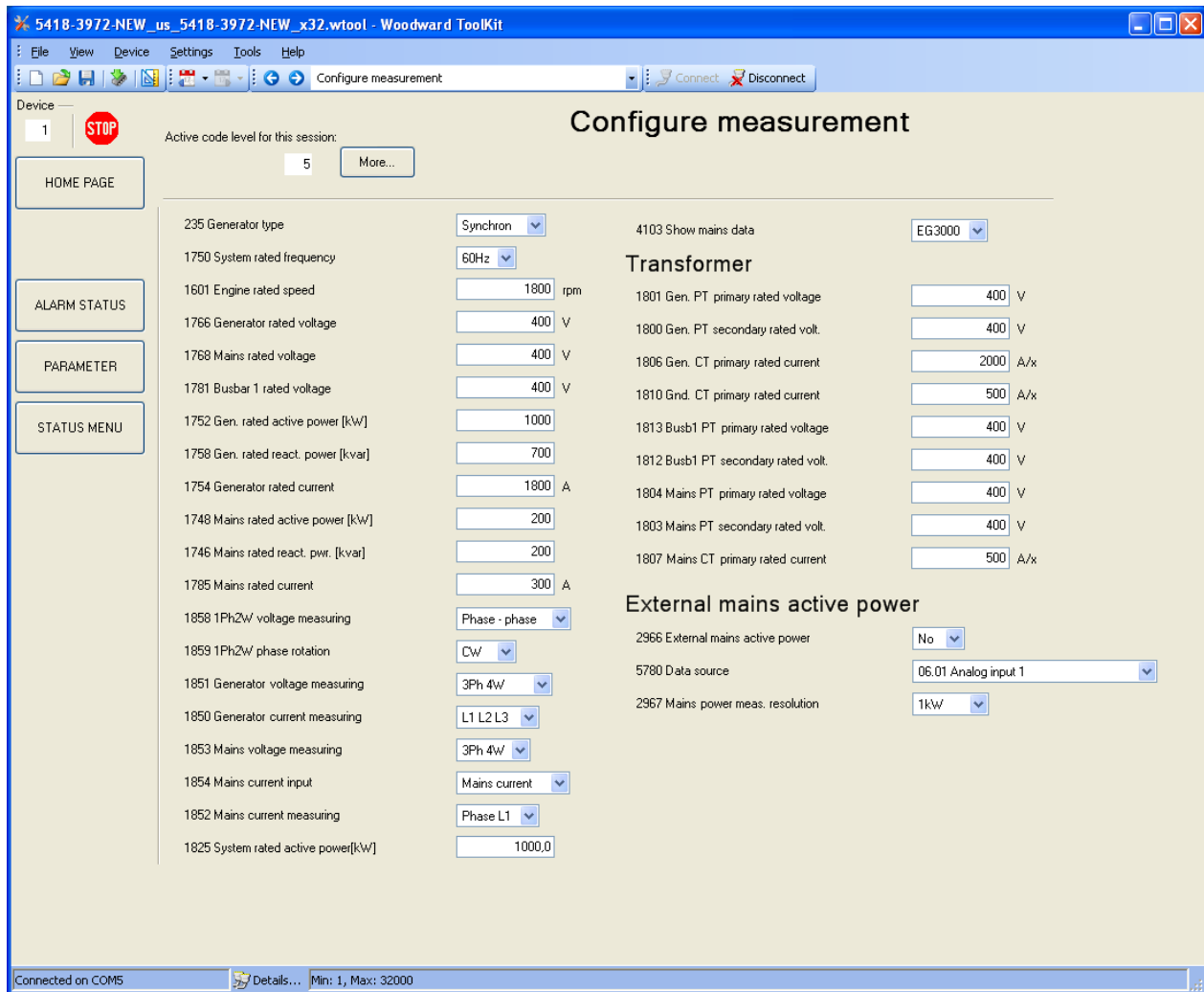
1. Introduction

A test of the behavior of the Easygen3500 at high harmonic load was performed. Focus was 11th harmonics in current and voltage. Base was a report of problems with load sharing at a site in Ecuador. For that the Easygen was fed with current and voltage of an OMICRON source and the measurement of power, reactive power and frequency was analyzed.

The Input is a measurement protocol of an EGCP-3. In the following figure the white curve shows the 11th harmonics current relative to the fundamental and the red curve shows the same for the voltage. Measurement time is about 2 minutes.



The Easygen3500 was configured in a way similar to the EGCP-3:

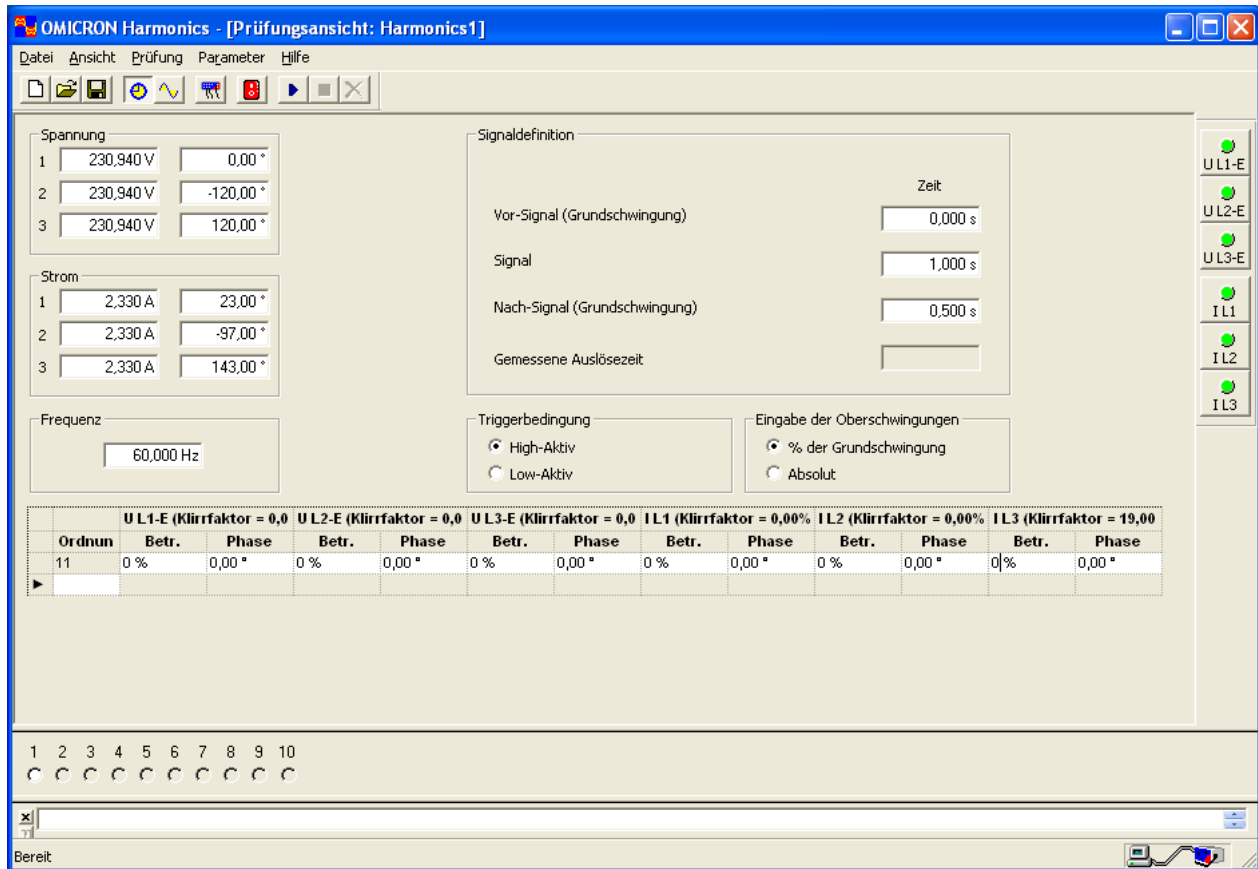


The easYgen is configured as follows:

- 400V /60Hz rated
- 1800A rated
- 2000/5 CT ratio
- 1000kW rated (Nominal Measurement is 1.38MW [400V / 2000A])

2. Measurement: No harmonics.

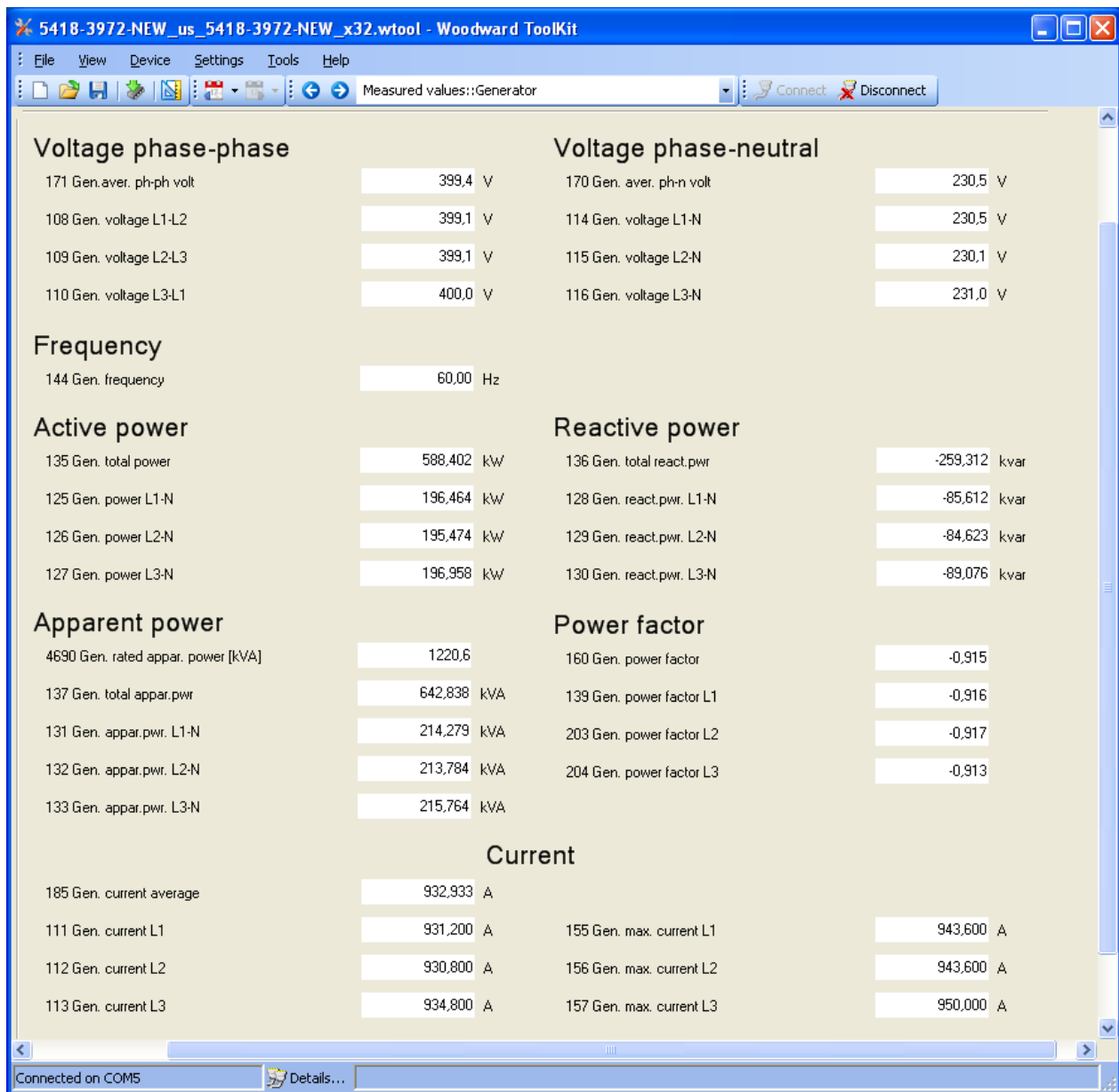
As reference the accuracy and jitter of the EasyGen3500 for undisturbed inputs was tested.



The OMICRON voltage generator is configured to:

- 400V/60Hz rated
- 2.33 A apparent current
- 23° (arccos of 0.91 PF)
- Voltage: No harmonics
- Current: No harmonics

This leads in the easYgen to following measurement data:

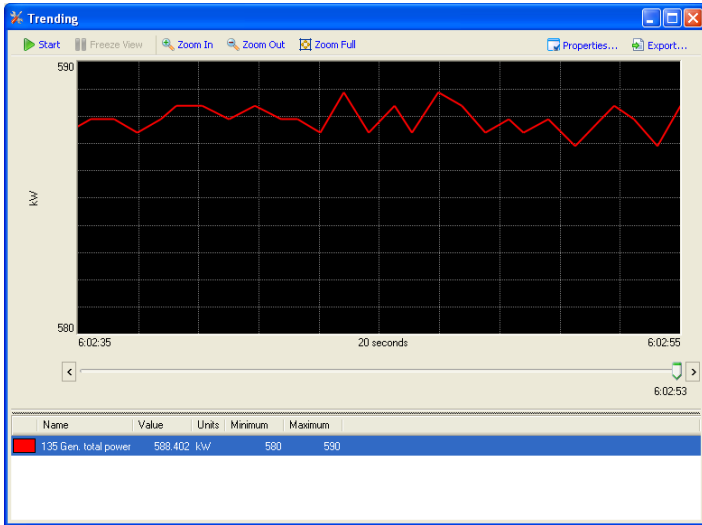


Theoretically $P=U \cdot I \cdot \cos\Phi \cdot 3 \cdot (\text{Transformer ratio}=400)$

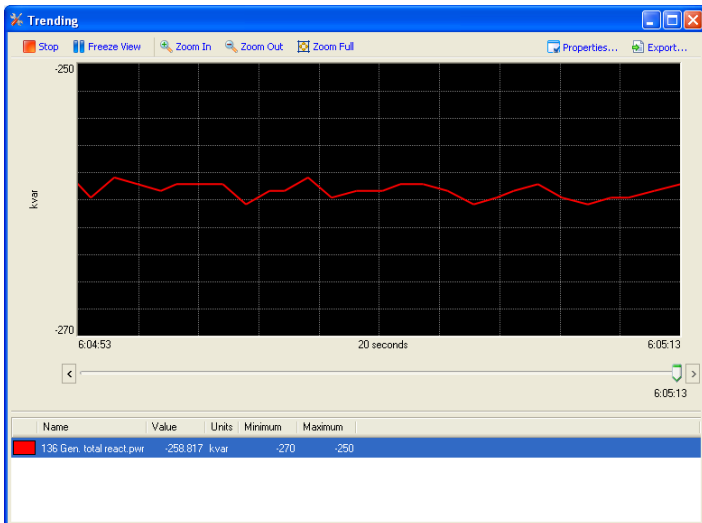
$$P= 230,94 \cdot 2,330 \cdot 0,9205 \cdot 3 \cdot 400 = 594,37\text{kW}$$

Difference is less than =0.45% related to nominal rated (1,38MW)

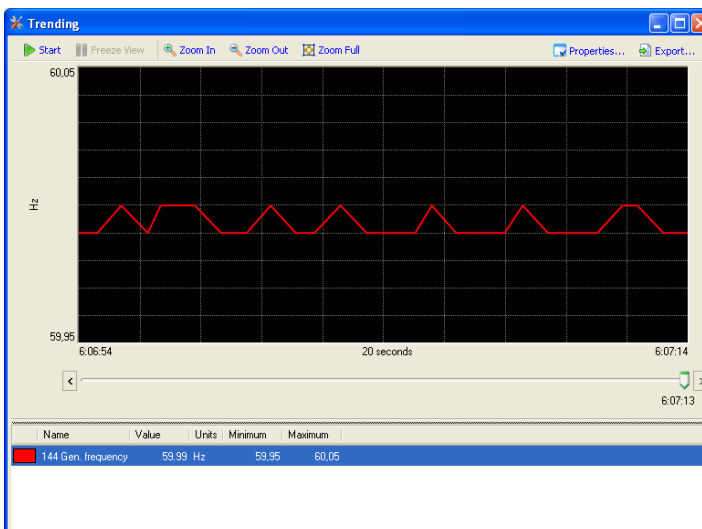
This is 4 times better as specified.



Maximum 2kW Jitter at 1000kW engine rated

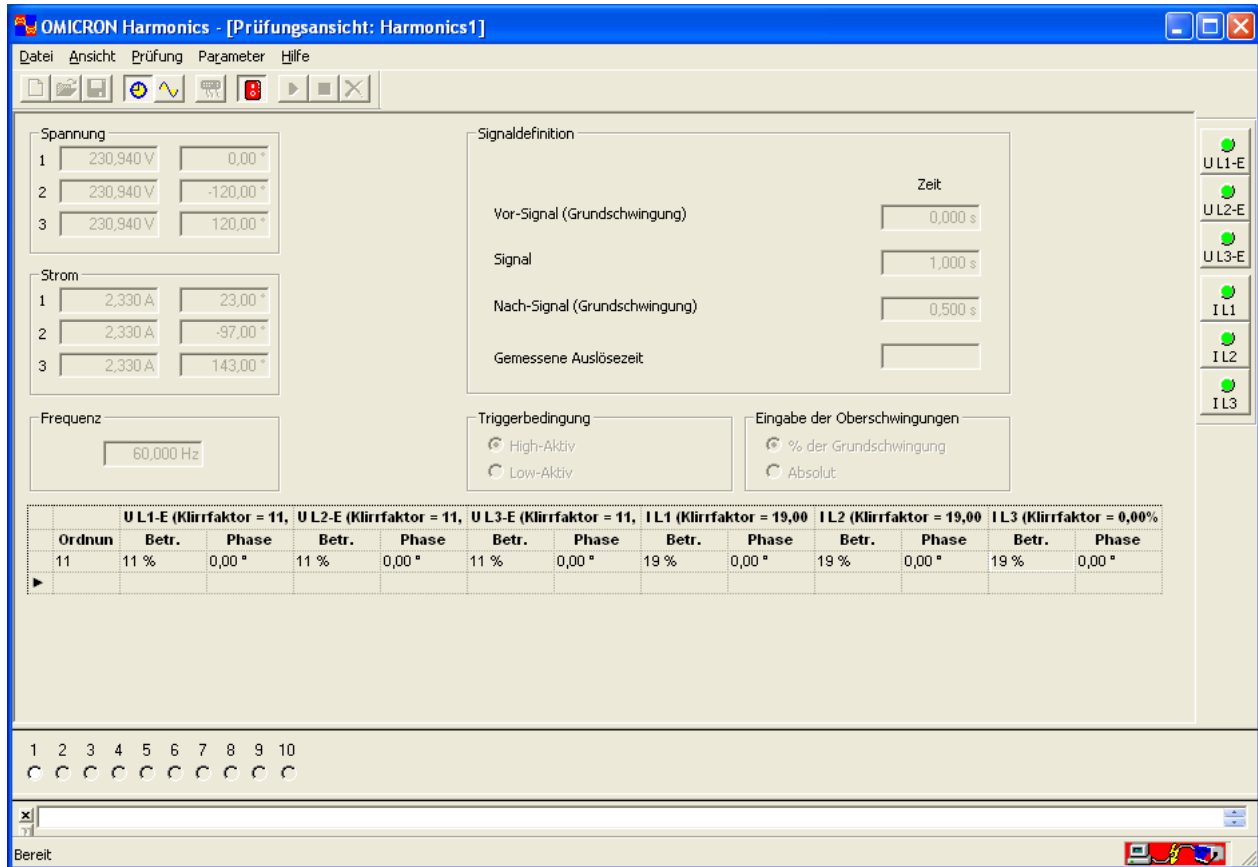


Max. 2kvar Jitter



Max. 0.01 Hz Jitter

3. Measurement: Harmonics according to the EGCP-3 example

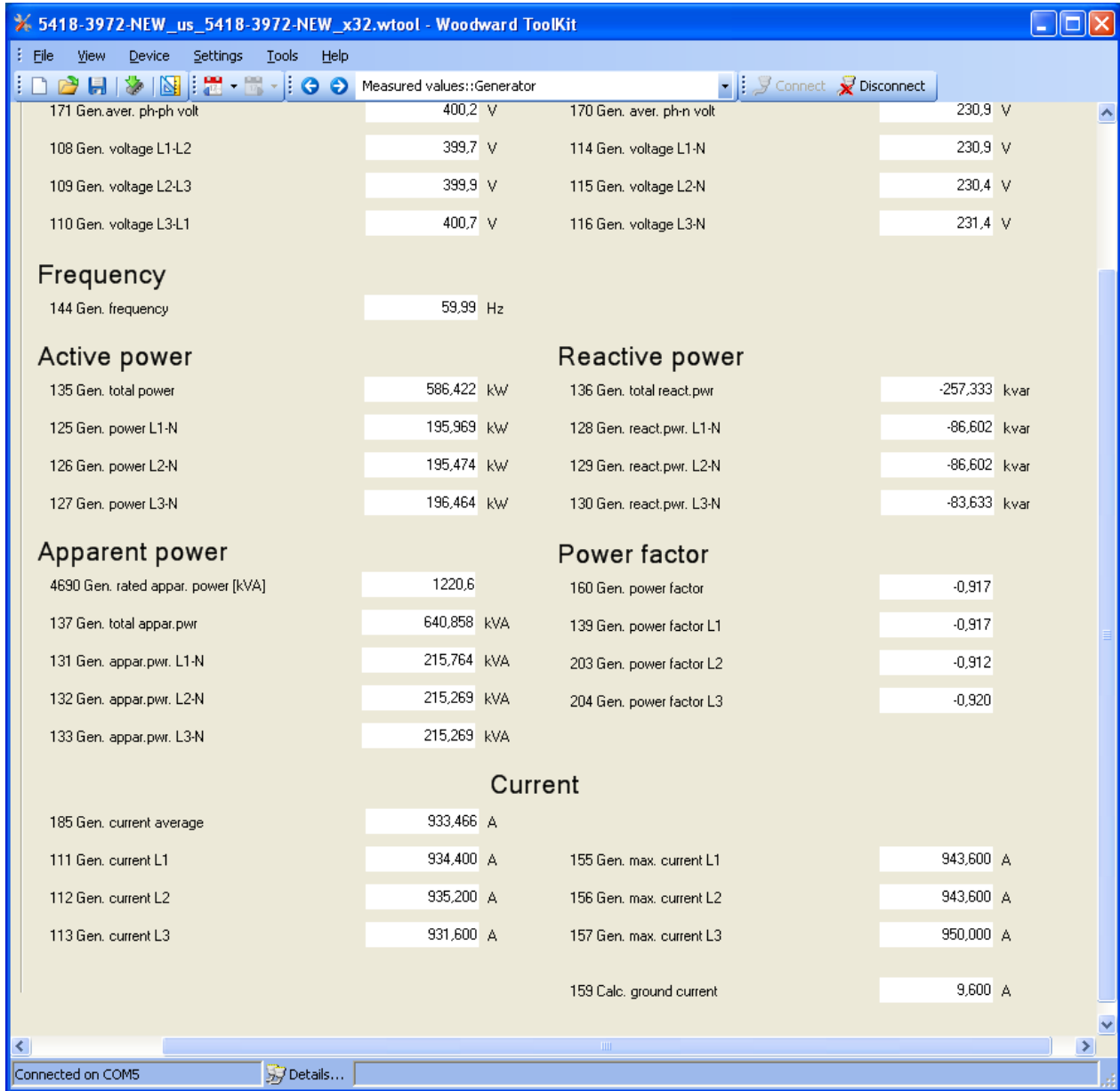


The OMICRON voltage generator is configured to:

- 400V/60Hz rated
- 2.33 A apparent current
- 23° (arccos of 0.91 PF)
- Voltage: Additional 11% of fundamental at 11th harmonics
- Current: Additional 19% of fundamental at 11th harmonics

These are the values from the EGCP-3 example.

This leads in the easYgen to following measurement data:



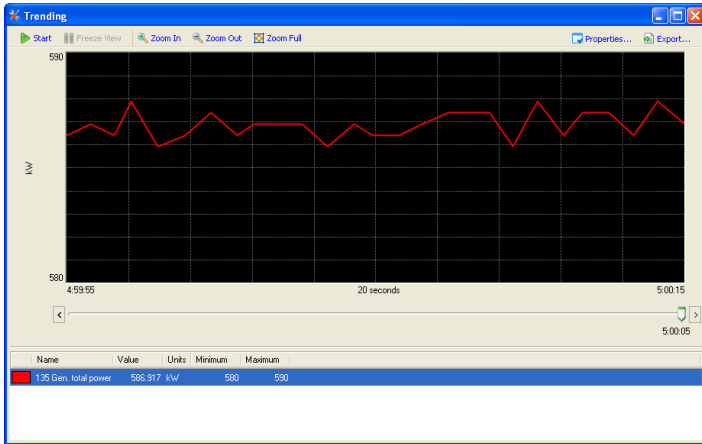
Theoretically $P=U \cdot I \cdot \cos\Phi \cdot 3 \cdot (\text{Harmonics part}) \cdot (\text{Transformer ratio})$

$$P = 230.94 \cdot 2.330 \cdot 0.9205 \cdot 3 \cdot (1 + 0.11 \cdot 0.19) \cdot 400 = 606,79 \text{ kW}$$

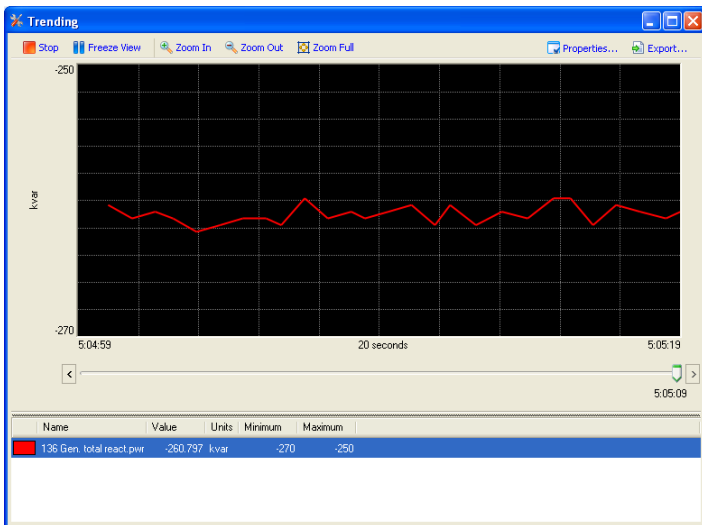
Difference is less than =1.45% nominal rated (1,38MW)

This is within the specification.

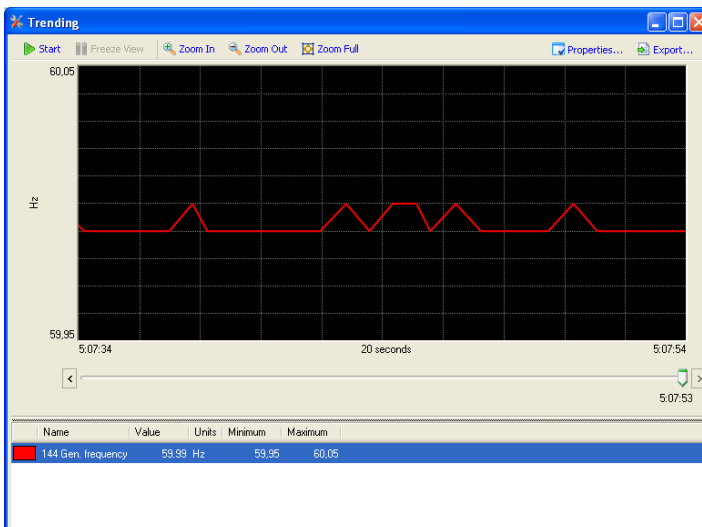
One reason for this difference is that the 11th harmonic part is filtered out by the easYgen Hardware.



Max. 2kW Jitter at 1000kW engine rated

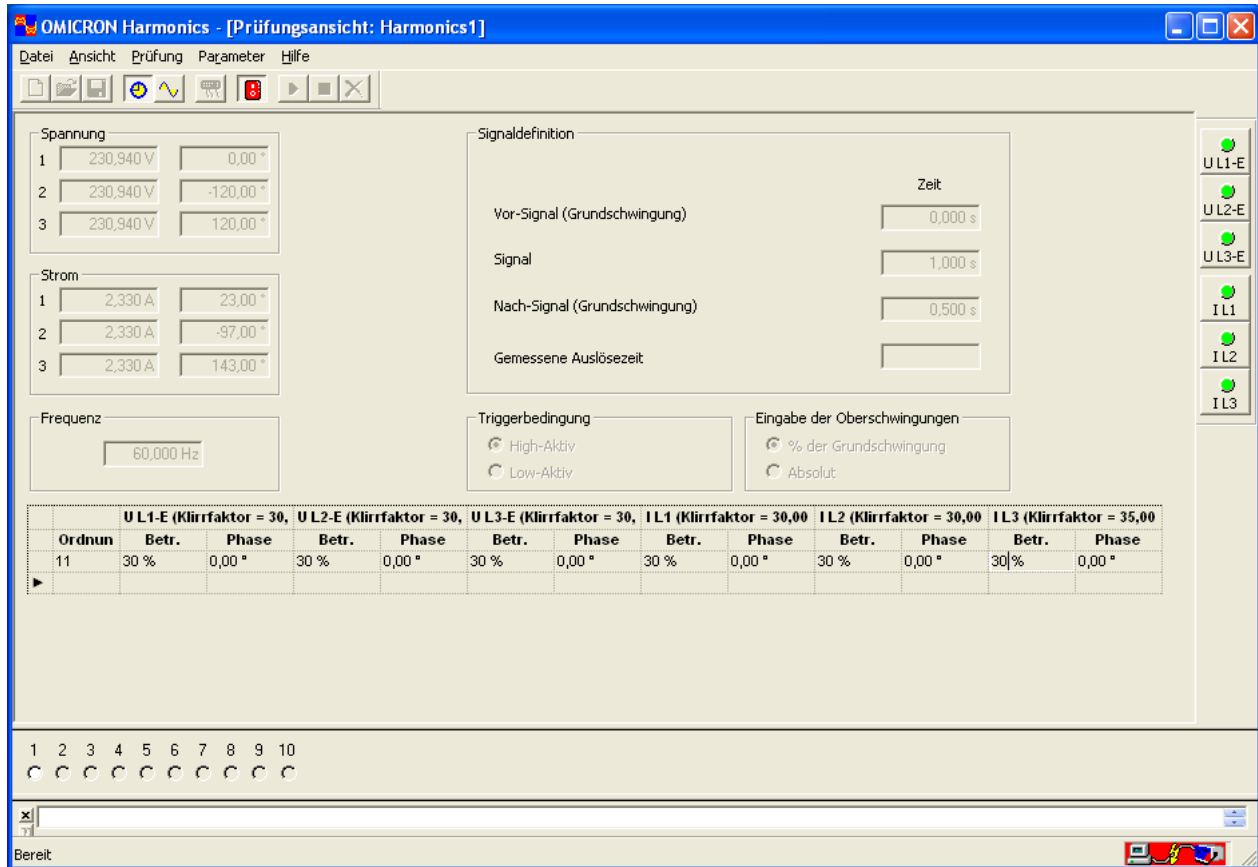


Max. 2kvar Jitter



Max. 0.01 Hz Jitter

4. Measurement: Strong Harmonics example



The OMICRON voltage generator is configured to:

- 400V/60Hz rated
- 2.33 A apparent current
- 23° (arccos of 0.91 PF)
- Voltage: Additional 30% of fundamental at 11th harmonics
- Current: Additional 30% of fundamental at 11th harmonics

These are very high demonstration values as an example.

This leads in the easYgen to following measurement data:

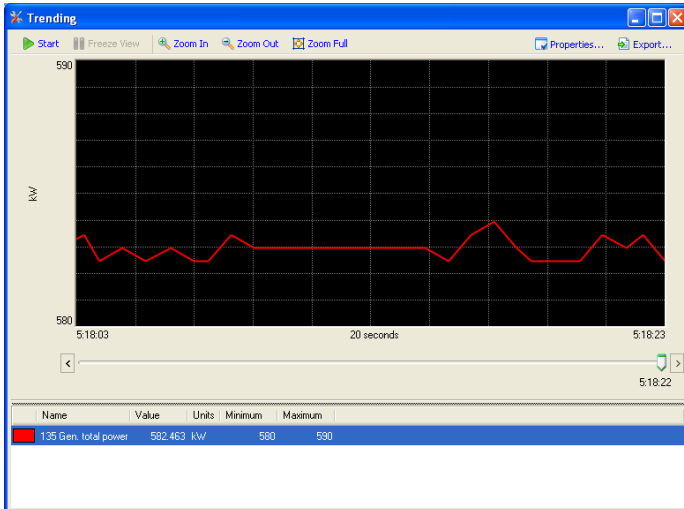
Measured values::Generator			
171 Gen. aver. ph-ph volt	404,4 V	170 Gen. aver. ph-n volt	233,4 V
108 Gen. voltage L1-L2	404,0 V	114 Gen. voltage L1-N	233,0 V
109 Gen. voltage L2-L3	404,5 V	115 Gen. voltage L2-N	233,0 V
110 Gen. voltage L3-L1	405,1 V	116 Gen. voltage L3-N	234,1 V
Frequency			
144 Gen. frequency	59,99 Hz		
Active power		Reactive power	
135 Gen. total power	582,463 kW	136 Gen. total react.pwr	-261,787 kvar
125 Gen. power L1-N	194,484 kW	128 Gen. react.pwr. L1-N	-86,602 kvar
126 Gen. power L2-N	193,989 kW	129 Gen. react.pwr. L2-N	-86,602 kvar
127 Gen. power L3-N	194,484 kW	130 Gen. react.pwr. L3-N	-88,087 kvar
Apparent power		Power factor	
4690 Gen. rated appar. power [kVA]	1220,6	160 Gen. power factor	-0,911
137 Gen. total appar.pwr	639,374 kVA	139 Gen. power factor L1	-0,919
131 Gen. appar.pwr. L1-N	219,228 kVA	203 Gen. power factor L2	-0,917
132 Gen. appar.pwr. L2-N	219,228 kVA	204 Gen. power factor L3	-0,919
133 Gen. appar.pwr. L3-N	221,207 kVA		
Current			
185 Gen. current average	943,333 A		
111 Gen. current L1	941,600 A	155 Gen. max. current L1	943,600 A
112 Gen. current L2	942,000 A	156 Gen. max. current L2	943,600 A
113 Gen. current L3	947,200 A	157 Gen. max. current L3	949,200 A
		159 Calc. ground current	8,000 A

Theoretically $P=U \cdot I \cdot \cos\Phi \cdot 3 \cdot (\text{Harmonics part}) \cdot (\text{Transformer ratio})$

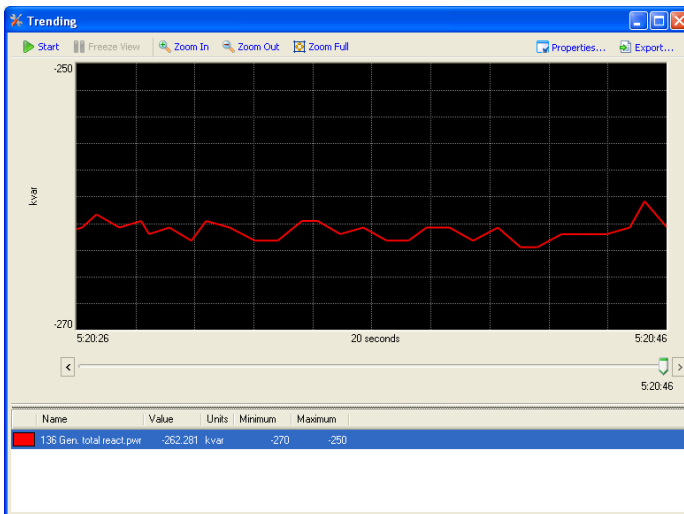
$$P = 230,94 \cdot 2,330 \cdot 0,9205 \cdot 3 \cdot (1 + 0,3 \cdot 0,3) \cdot 400 = 647,8 \text{ kW}$$

Difference is less than =4.8% nominal rated (1,38MW)

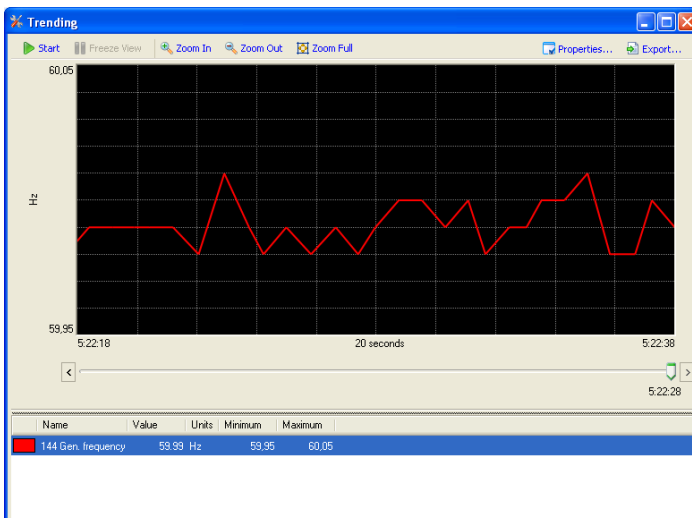
One reason for this difference is that the 11th harmonic part is filtered out by the easYgen Hardware.



Max. 2kW Jitter at 1000kW engine rated



Max. 4kvar Jitter



Max. 0.03 Hz Jitter

5. Results and Conclusions

Results

- Test at reported conditions
 - Instability of the Easygen's measurement at the reported conditions (19% for current and 11% for voltage at 11th harmonics) could not be confirmed. The jitter is same as in the undisturbed measurement and significantly smaller than the accuracy specification
 - The absolute measurement error was larger than in the undisturbed measurement but still in the specified range
- Test at higher distortions
 - At significant higher distortions (30% for current and 30% for voltage at 11th harmonics) a higher measurement jitter was visible. The jitter is still significantly smaller than the accuracy specification
 - The absolute measurement error was larger than specified. The reason is considered the hardware filter which filters out most of the 11th harmonics content

Restrictions

The data from the field were not very detailed. Showed values for the distortion was only total harmonic content and that this mostly contains the 11th harmonics was only communicated verbally.

Conclusions

We assume that the reported instability of the Easygen was not caused by instability of the AC measurement due high harmonics content. A more probable source may be improper PID settings or other regulation setting. However, our tests were only cursory and the reported data was not complete so there is still the chance that our tests missed something