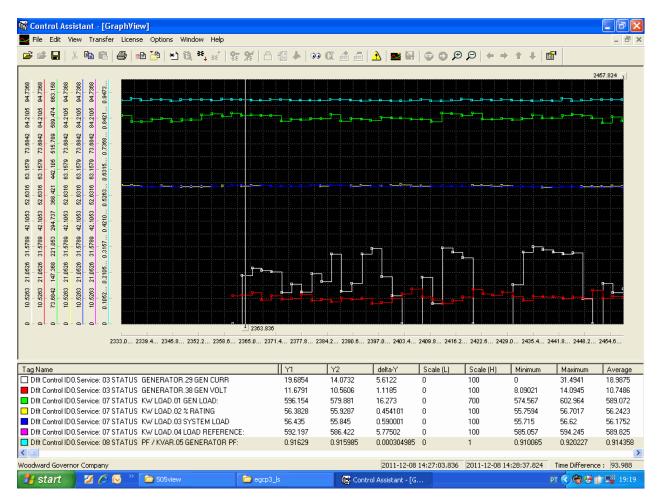
Harmonic Stress Test easYgen3500 TL: 8440-3934

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.



5418-3972-NEW	_us_5418-3972-NEW_x32.wtool - Woodward : <u>S</u> ettings <u>T</u> ools <u>H</u> elp	ToolKit						
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I STOP	Active code level for this session: 5 More	Configure measurement						
)	235 Generator type	Synchron 💌	4103 Show mains data	EG3000 🖌				
	1750 System rated frequency	60Hz 💌	Transformer					
LARM STATUS	1601 Engine rated speed	1800 rpm	1801 Gen. PT primary rated voltage	400 V				
LANK STATUS	1766 Generator rated voltage	400 V	1800 Gen. PT secondary rated volt.	400 V				
PARAMETER	1768 Mains rated voltage	400 V	1806 Gen. CT primary rated current	2000 A/x				
	1781 Busbar 1 rated voltage	400 V	1810 Gnd. CT primary rated current	500 A/x				
TATUS MENU	1752 Gen. rated active power [kW]	1000	1813 Busb1 PT primary rated voltage	400 V				
	1758 Gen. rated react. power [kvar]	700	1812 Busb1 PT secondary rated volt.	400 V				
	1754 Generator rated current	1800 A	1804 Mains PT primary rated voltage	400 V				
	1748 Mains rated active power [kW]	200	1803 Mains PT secondary rated volt.	400 V				
	1746 Mains rated react, pwr. [kvar]	200	1807 Mains CT primary rated current	500 A/x				
	1785 Mains rated current	300 A	— , , , ,					
	1858 1Ph2W voltage measuring	Phase - phase 🔽	External mains active p					
	1859 1Ph2W phase rotation	CW 💌	2966 External mains active power	No 💌				
	1851 Generator voltage measuring	3Ph 4W 🔽	5780 Data source	06.01 Analog input 1				
	1850 Generator current measuring	L1 L2 L3 💌	2967 Mains power meas, resolution	1kW 🔽				
	1853 Mains voltage measuring	3Ph 4W 🔽						
	1854 Mains current input	Mains current						
	1852 Mains current measuring	Phase L1 💌						
	1825 System rated active power[kW]	1000,0						
ected on COM5	💭 Details Min: 1, Max: 32000							

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.

		nics - [Prüfur		Harmonics	s1]									
		Pa <u>r</u> ameter <u>F</u>												
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Frequenz	Frequenz 60,000 Hz								der Grundsch solut	Oberschwingungen Grundschwingung t				
Ordnu			Betr.	Phase	Betr.	Phase	Betr.	Phase	Betr.	Phase	Betr.	Phase		
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000		7891 CCCC												
X														
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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

5418-3972-NEW_us_5418-3972-NEW_x	32.wtool - Woodward	ToolKit	
	Measured values::General	tor 🚽 📝 Connect 🦼 Di	isconnect
Voltage phase-phase		Voltage phase-neutral	
171 Gen.aver. ph-ph volt	399,4 V	170 Gen. aver. ph-n volt	230,5 V
108 Gen. voltage L1-L2	399,1 V	114 Gen. voltage L1-N	230,5 V
109 Gen. voltage L2-L3	399,1 V	115 Gen. voltage L2-N	230,1 V
110 Gen. voltage L3-L1	400,0 V	116 Gen. voltage L3-N	231,0 V
Frequency			
144 Gen. frequency	60,00 Hz		
Active power		Reactive power	
135 Gen. total power	588,402 kW	136 Gen. total react.pwr	-259,312 kvar
125 Gen. power L1-N	196,464 kW	128 Gen. react.pwr. L1-N	-85,612 kvar
126 Gen. power L2-N	195,474 kW	129 Gen. react.pwr. L2-N	-84,623 kvar
127 Gen. power L3-N	196,958 kW	130 Gen. react.pwr. L3-N	-89,076 kvar
Apparent power		Power factor	
4690 Gen. rated appar. power [kVA]	1220,6	160 Gen. power factor	-0,915
137 Gen. total appar.pwr	642,838 kVA	139 Gen. power factor L1	-0,916
131 Gen. appar.pwr. L1-N	214,279 kVA	203 Gen. power factor L2	-0,917
132 Gen. appar.pwr. L2-N	213,784 kVA	204 Gen. power factor L3	-0,913
133 Gen. appar.pwr. L3-N	215,764 kVA		
	Cu	rrent	
185 Gen. current average	932,933 A		
111 Gen. current L1	931,200 A	155 Gen. max. current L1	943,600 A
112 Gen. current L2	930,800 A	156 Gen. max. current L2	943,600 A
113 Gen. current L3	934,800 A	157 Gen. max. current L3	950,000 A
			>
nnected on COM5 🦙 Details			

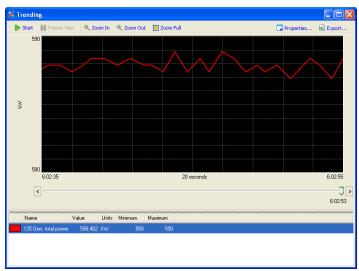
This leads in the easYgen to following measurement data:

Theoretically P=U*I*cosPhi*3 * (Transformer ratio=400)

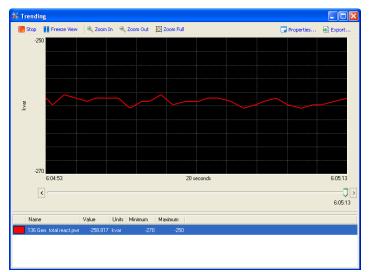
P= 230.94 * 2.330 * 0.9205 * 3 * 400 = 594,37kW

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

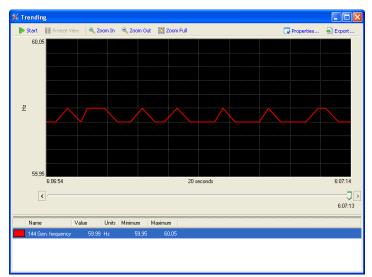
This is 4 times better as specified.



Maximum 2kW Jitter at 1000kW engine rated



Max. 2kvar Jitter



Max. 0.01 Hz Jitter

EG3500 Measurement Test

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

			ics - [Prüfur		Harmonics	s1]								
_			Parameter <u>H</u>											
	nnung – 230, 230, 230, 230, 230, 2, 2, 2,	940 V 940 V 940 V 940 V 330 A 330 A 330 A	0,00° -120,00° 120,00° 23,00° -97,00° 143,00°		1	Signal Nach-Si	nition nal (Grundschw gnal (Grundsch iene Auslöseze	wingung)		ן ן ן ן	Zeit 0,000 s 1,000 s 0,500 s			ULI-E ULI-E UL2-E UL3-E UL3-E IL1 IL2
Freq	juenz	60,000 H				C Low-	Aktiv Aktiv				hwingung		-14 0.000	IL3
	rdnun		Phase	Betr.	Phase	Betr.	Phase	Betr.	Phase	Betr.	Phase	Betr.	Phase	
11		11 %	0,00 °	11 %	0,00 °	11 %	0,00 °	19 %	0,00 "	19 %	0,00 °	19 %	0,00 "	
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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.

5418-3972-NEW_us_5418-3972-NEW_x3 File View Device Settings Tools Help	2.wtool - Woodwa	ırd ToolKit	
	Measured values::Ger	ierator 🗸 🛛 🍠 Connect 🦼	Disconnect
171 Gen.aver. ph-ph volt	400,2 V		230,9 V
108 Gen. voltage L1-L2	399,7 V	114 Gen. voltage L1-N	230,9 V
109 Gen. voltage L2-L3	399,9 V	115 Gen. voltage L2·N	230,4 V
110 Gen. voltage L3-L1	400,7 V	116 Gen. voltage L3-N	231,4 V
Frequency			
144 Gen. frequency	59,99 H	z	
Active power		Reactive power	
135 Gen. total power	586,422 k		-257,333 kvar
125 Gen. power L1-N	195,969 k		-86,602 kvar
126 Gen. power L2-N	195,474 k	·	-86,602 kvar
127 Gen. power L3-N	196,464 k ^a	·	-83,633 kvar
Apparent power		Power factor	
4690 Gen. rated appar. power [kVA]	1220,6	160 Gen. power factor	-0.917
137 Gen. total appar.pwr	640,858 KV		-0,917
131 Gen. appar.pwr. L1-N	215,764 KV		-0.912
132 Gen. appar.pwr. L2-N	215,269 KV		-0.920
133 Gen. appar.pwr. L3-N	215,269 kV		0,020
		Current	
185 Gen. current average	933,466 A		
111 Gen. current L1	934,400 A	155 Gen. max. current L1	943,600 A
112 Gen. current L2	935,200 A	156 Gen. max. current L2	943,600 A
113 Gen. current L3	931,600 A	157 Gen. max. current L3	950,000 A
		159 Calc. ground current	9,600 A
nnected on COM5 🙀 Details			>

This leads in the easYgen to following measurement data:

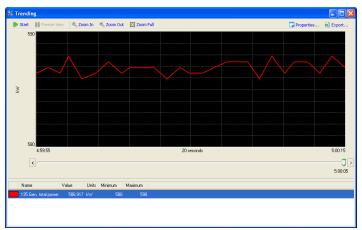
Theoretically P=U*I*cosPhi*3 * (Harmonics part) * (Transformer ratio)

P= 230.94*2.330*0.9205*3*(1+0.11*0.19)*400= 606,79kW

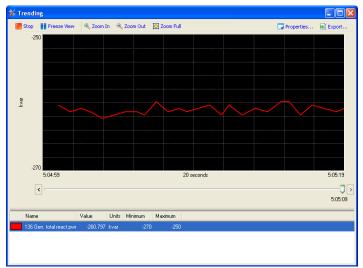
Difference is less than =1.45% nominal rated (1,38MW)

This is within the specification.

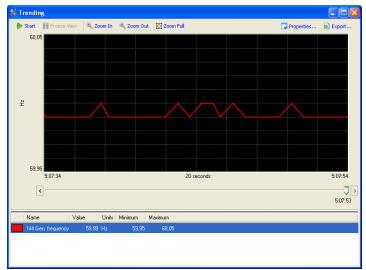
One reason for this difference is that the 11th harmonic part is filtered out by the easYgen Hardware.



Max. 2kW Jitter at 1000kW engine rated



Max. 2kvar Jitter



Max. 0.01 Hz Jitter

4. Measurement: Strong Harmonics example

			<mark>ics - [Prüfun</mark> Pa <u>r</u> ameter <u>H</u>		Harmonics	:1]								
_														
1 2 3 	230 230 om 2 2 2 2 2 2	.940 V 940 V 940 V 330 A 330 A 330 A 330 A 330 A 330 A S40 V S40	0.00 ° -120.00 ° 120.00 ° 23.00 ° -97.00 ° 143.00 °		<u>.</u>	Signal Nach-Si Gemess	nal (Grundschw gnal (Grundsch ene Auslösezei	wingung)		 	Zeit 0,000 s 1,000 s 0,500 s			9 UL1-E 9 UL2-E 9 UL3-E 9 IL1 9 IL1 9 IL2 9 IL3
Fre	equenz —	60,000 H				C Low-	Aktiv Aktiv		©% o C Abs	der Grundsc :olut				
	Ordnun		lirrfaktor = 30, Phase	U L2-E (Kliri Betr.		UL3-E (Kli Betr.	rrfaktor = 30, Phase	IL1 (Klirr Betr.	faktor = 30,00 Phase	I L2 (Klirr Betr.	faktor = 30,00 Phase	IL3 (Klirri Betr.	aktor = 35,00 Phase	
	oranun 11	вец. 30 %	0,00 °		Phase 0.00 °	вец. 30 %	0,00 °	вец. 30 %	0,00 °	вец. 30 %	0.00 °	вец. 30 %	0,00 °	
►		30 %	0,00	30 %	0,00	30 %	0,00	30 %	0,00	30 %	0,00	00 %	0,00	
			7891 CCCC					<u></u>				<u></u>		
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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.

¥ 5418-3972-NEW_us_5418-3972-NEW_x3	2.wtool - Wood	ward To	olKit		
Eile View Device Settings Tools Help					
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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	k₩	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			
		Curr	ent		
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	А	157 Gen. max. current L3	949,200	A
			159 Calc. ground current	8,000	A
<					×
Connected on COM5					

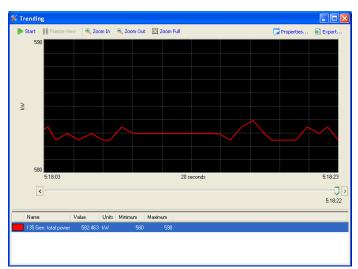
This leads in the easYgen to following measurement data:

Theoretically P=U*I*cosPhi*3 * (Harmonics part) * (Transformer ratio)

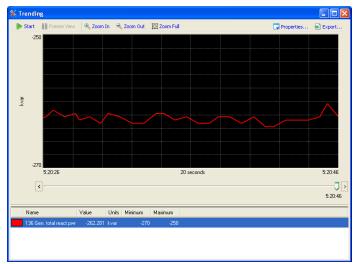
P= 230.94*2.330*0.9205*3*(1+0.3*0.3)*400= 647,8kW

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

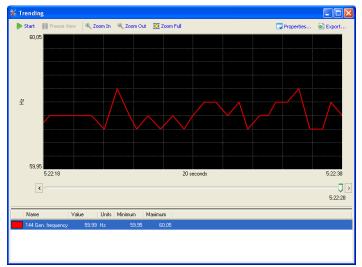
One reason for this difference is that the 11th harmonic part is filtered out by the easYgen Hardware.







Max. 4kvar Jitter



Max. 0.03 Hz Jitter

EG3500 Measurement Test

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, out tests were only cursory and the reported data was not complete so there is still the chance that our tests missed something