



Measurement of Harmonics

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PROBLEMS DUE TO HARMONICS

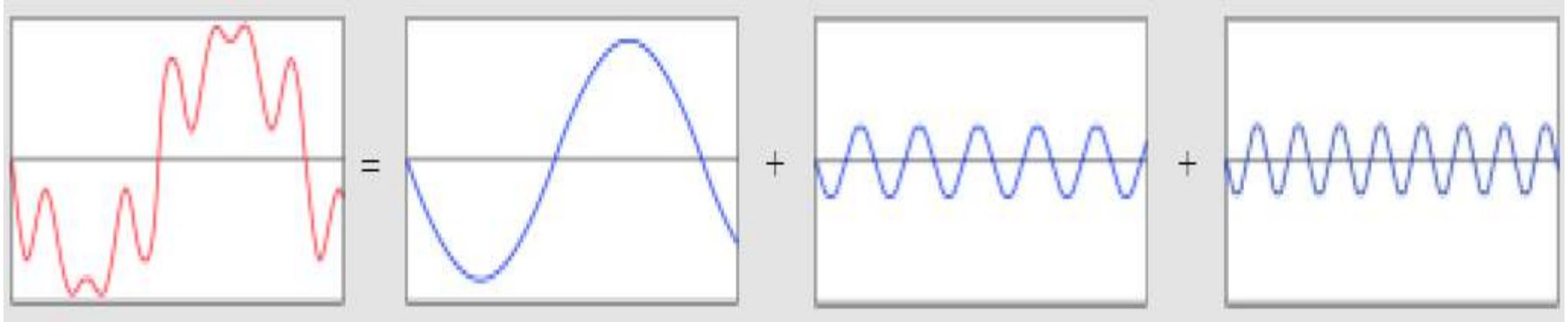
- * Malfunctioning of control systems since electronic meters, relays, etc. are matched to the fundamental frequency.**
- * Overloading of capacitors, leading to malfunctioning and premature ageing.**
- * Miss-operation or failure of electronic equipment.**
- * Interference with telecommunications and computers.**
- * Increased losses, e.g. machines will operate at increased temperature and can be overheated.**
- * Resonance problems between the inductive and capacitive parts of the power network.**
- * Disturbances in ripple control systems.**
- * High currents in neutral conductors.**



A pure voltage or current sine wave has no distortion and no harmonics, and a non-sinusoidal wave has distortion and harmonics. To quantify the distortion, the term Total Harmonic Distortion (THD) is used. The term expresses the distortion as a percentage of the fundamental (pure sine) of voltage and current waveforms.

The distorted curve consists both of the fundamental frequency (e.g. 50 Hz) and of superimposed 5th (250 Hz) and 7th (350 Hz) harmonic frequencies.

Distorted wave (Pure sine wave 50 Hz) (5th Harmonic 250 Hz) (7th harmonic 350 Hz)





STANDARDS AND PERMISSIBLE LIMITS FOR HARMONICS

IEEE 519-1992 Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems and provides guidelines for determining acceptable limits. The harmonic limits for current depend on the ratio of Short Circuit Current (SCC) at PCC (or how stiff it is) to average Load Current.

**CURRENT DISTORTION LIMITS FOR GENERAL DISTRIBUTION SYSTEMS****(120V through 69 000V)**

Maximum Harmonic Current Distortion in % of I_L						
Individual Harmonic Order (Odd Harmonics)						
I_{SC}/I_L	< 11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	TDD
$< 20^*$	4.0	2.0	1.5	0.6	0.3	5.0
$20 < 50$	7.0	3.5	2.5	1.0	0.5	8.0
$50 < 100$	10.0	4.5	4.0	1.5	0.7	12.0
$100 < 1000$	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

Even harmonics are limited to 25% of the odd harmonic limits.

Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

*All power generation equipment is limited to these values of current distortion, regardless of actual I_{SC}/I_L .

Where
 I_{SC} = maximum short-circuit current at PCC
 I_L = maximum demand load current (fundamental frequency component) at PCC.

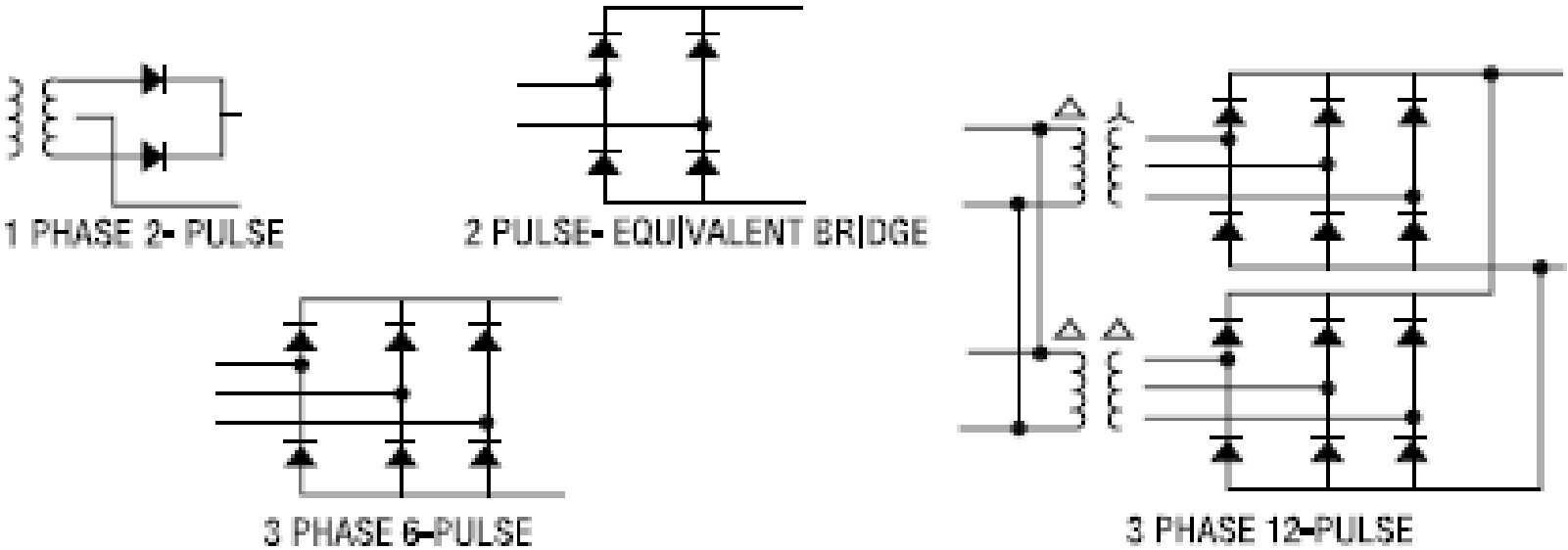


VOLTAGE DISTORTION LIMITS

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69 kV and below	3.0	5.0
69.001 kV to 161 kV	1.5	2.5
161 kV and above	1.0	1.5

NOTE: High voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.

TYPE OF PULSE AND HARMONICS



PULSE#	CHARACTER STIC HARMONICS
2	3rd, 5th, 7th, 9th, 11th, 13th, 15th, 17th, 19th, ...
6	5th, 7th, 11th, 13th, 17th, 19th, 23rd, 25th, ...
12	11th, 13th, 23rd, 25th, 35th, 37th, ...
18	17th, 19th, 35th, 37th, 53rd, 55th, ...

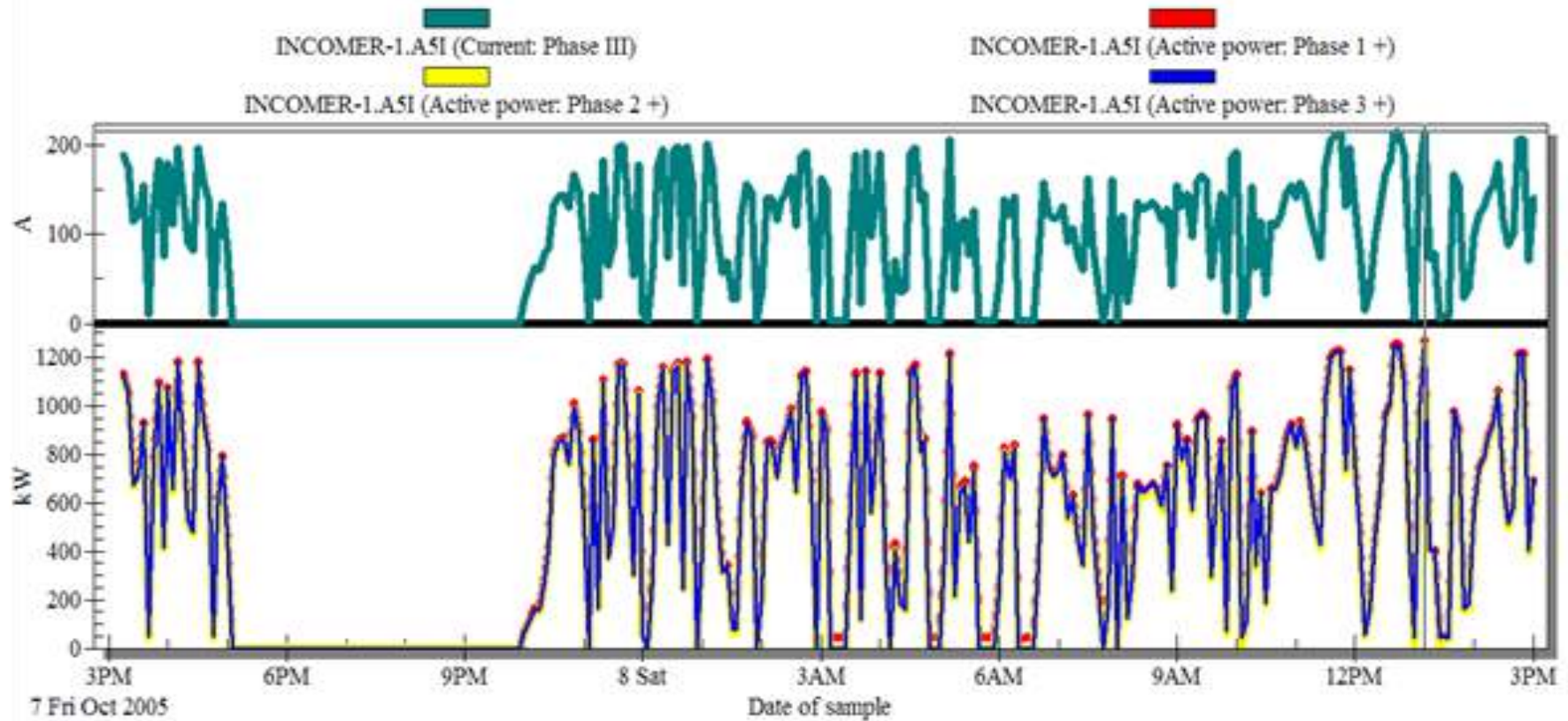
Table - 1 Measured Voltage and Current THD at different points & locations

Particulars		110/11 kV SS			KCPL	AVT (LJ)	KERA	THAPASYA	Chiller Plant	TCS UPS Feeder	
		Trans. No.1	Trans. No.2	KOYENCO Feeder							
		PCC - 1	PCC - 2	1							
Transformer kVA		10000	10000	4200	1600	500	750	750	1000	1000	
Voltage	HV	110000	110000	11000	11000	11000	11000	11000	11000	11000	
	LV	11000	11000	850/850	433	433	433	433	433	433	
Current	HV	52.5	52.5	220.44	83.97	26.24	39.36	39.36	52.5	52.5	
	LV	525.0	525.0	1426/1426	2133.4	666.6	1000.0	1000.0	1333.0	1333.0	
Impedance	%	9.965	9.965	8.0	6.099	5.03	4.98	5	6.19	6.19	
Short Circuit Current I _{sc}		5268.44	5268.44	2238.48	34979.50	13252.49	20080.32	20000.00	21534.73	NA	
Measured Max. demand load Current (Fundamental) I _L at PCC		216.595	145.442	203.854	1660	158.866	865.619	973	280	79.38	
IEEE-519, 1992, permissible Voltage THD is 5 %		Phase	THD %	THD %	THD %	THD %	THD %	THD %	THD %	THD %	
Measured % of THD at maximum demand load (Fundamental) current (I _L)	V	R	5.3	1.4	6.8	1.3	1.1	1.2	1.3	2.0	
		Y	5.5	1.5	6.3	1.4	1.3	1.1	1.1	2.2	
		B	6.1	1.5	7.2	1.3	1.3	1.4	1.4	2.1	
	A	R	4.1	1.2	3.7	1.3	5.0	3.4	7.4	3.4	15.5
		Y	3.8	1.3	3.6	1.7	4.6	3.6	8.2	3.6	16.2
		B	4.1	1.4	3.8	1.7	4.6	3.5	2.3	3.5	16.1
IEEE-519, 1992, TDD %		8.0	8.0	5	8.0	12.0	8.0	8.0	12.0	5.0	
IEEE-519, 1992, I _{sc} /I _L range		20 < 50	20 < 50	<20	20 < 50	50 < 100	20 < 50	20 < 50	50 < 100	<20	
I _{sc} /I _L		24.32	36.22	10.98	21.07	83.42	23.20	20.55	76.91	NA	

Particulars			110 /11 kV SS							KCPL		AVT (LJ)	
			Trans. No.1		Trans. No.2		KOYENCO Feeder						
			PCC - 1		PCC - 2		1			PCC - 3		PCC - 4	
IEEE-519, 1992, TDD %			8.0		8.0		5			8.0		12.0	
IEEE-519, 1992, I _{sc} /I _L			20 < 50		20 < 50		<20			20 < 50		50 < 100	
Calculated I _{sc} /I _L			24.32		36.22		10.98			21.07		83.42	
IEEE-519, 1992, permissible % of individual Voltage harmonic is 3 %			Harmonic order	Measured % of individual harmonics									
				V	I	V	I	V	I	V	I	V	I
			2	0.250	0.210	0.296	0.311	0.543	0.477	0.471	0.459	0.357	0.813
			3	0.780	0.359	0.480	0.883	0.596	0.679	0.483	1.168	0.393	3.371
			4	0.119	0.315	0.209	0.066	0.176	0.234	0.200	0.163	0.134	0.134
			5	1.213	1.135	1.307	1.264	1.246	0.752	1.085	1.131	1.051	2.769
			6	0.307	0.361	0.129	0.066	0.242	0.199	0.153	0.167	0.088	0.112
			7	0.376	0.816	0.406	0.363	0.308	0.688	0.644	0.701	0.239	0.710
I _{sc} /I _L	Max. harmonic current distortion in %		8	0.223	0.228	0.131	0.091	0.320	0.235	0.108	0.094	0.064	0.135
			9	0.295	0.232	0.147	0.154	0.258	0.198	0.116	0.104	0.120	0.951
			10	0.274	0.226	0.072	0.068	0.407	0.335	0.127	0.070	0.063	0.091
	Harmonic order		11	3.015	3.051	0.219	0.241	3.589	2.784	0.163	0.144	0.368	0.907
	< 11	11 ≤ h ≤ 17	12	0.392	0.176	0.192	0.090	0.550	0.379	0.062	0.075	0.082	0.291
< 20	4	2	13	2.690	1.970	0.263	0.126	2.977	1.682	0.090	0.219	0.550	2.142
20 < 50	7	3.5	14	0.451	0.153	0.121	0.062	0.532	0.259	0.117	0.053	0.067	0.284
50 < 100	10	4.5	15	0.572	0.239	0.123	0.057	0.462	0.214	0.120	0.073	0.199	0.701
			16	0.751	0.225	0.097	0.029	0.713	0.289	0.061	0.063	0.158	0.585
			17	2.891	1.200	0.093	0.070	3.018	1.045	0.067	0.050	0.199	1.054
			18	1.671	0.744	0.055	0.025	1.870	0.500	0.065	0.042	0.054	0.169
			19	1.903	0.767	0.095	0.071	2.675	0.852	0.083	0.040	0.089	0.512
			20	1.496	0.640	0.103	0.035	1.536	0.431	0.093	0.064	0.042	0.119

Particulars			KERA		THAPASYA		Chiller Plant		TCS	
			PCC - 5		PCC - 6		PCC - 7			
IEEE-519, 1992, TDD %			8.0		8.0		12.0			
IEEE-519, 1992, I _{sc} /I _L			20 < 50		20 < 50		50 < 100			
Calculated I _{sc} /I _L			23.20		20.55		76.91			
IEEE-519, 1992, permissible % of individual Voltage harmonic is 3 %			Harmonic order	Measured % of individual harmonics						
				V	I	V	I	V	I	V
			2	0.154	0.337	0.385	1.269	0.109	0.369	0.042
			3	0.211	2.396	0.402	6.906	0.591	2.531	0.385
			4	0.066	0.145	0.156	0.334	0.040	0.155	0.065
			5	1.011	2.687	1.068	1.141	0.533	1.059	1.563
			6	0.028	0.111	0.102	0.310	0.036	0.209	0.032
I _{sc} /I _L	Max. harmonic current distortion in %	7	0.327	1.137	0.389	1.441	0.274	0.768	0.799	
		8	0.054	0.154	0.036	0.234	0.038	0.117	0.040	
		9	0.057	0.251	0.159	3.874	0.029	0.118	0.077	
		10	0.054	0.129	0.067	0.125	0.030	0.118	0.027	
		Harmonic order	11	0.217	0.849	0.606	0.528	0.162	0.339	0.807
	< 11	11 ≤ h ≤ 17	12	0.169	0.236	0.052	0.082	0.029	0.103	0.044
< 20	4	2	13	0.680	1.108	0.486	0.515	0.319	0.126	0.723
20 < 50	7	3.5	14	0.055	0.092	0.060	0.090	0.021	0.046	0.016
50 < 100	10	4.5	15	0.136	0.153	0.134	0.688	0.027	0.065	0.438
			16	0.178	0.277	0.081	0.117	0.019	0.039	0.038
			17	0.239	0.316	0.147	0.150	0.068	0.106	0.684
			18	0.118	0.179	0.390	0.055	0.038	0.021	0.031
			19	0.188	0.260	0.076	0.070	0.113	0.071	0.206
			20	0.067	0.035	0.270	0.051	0.040	0.054	0.026

GRAPH OF INCOMER - 1 POWER & CURRENT DETAILS



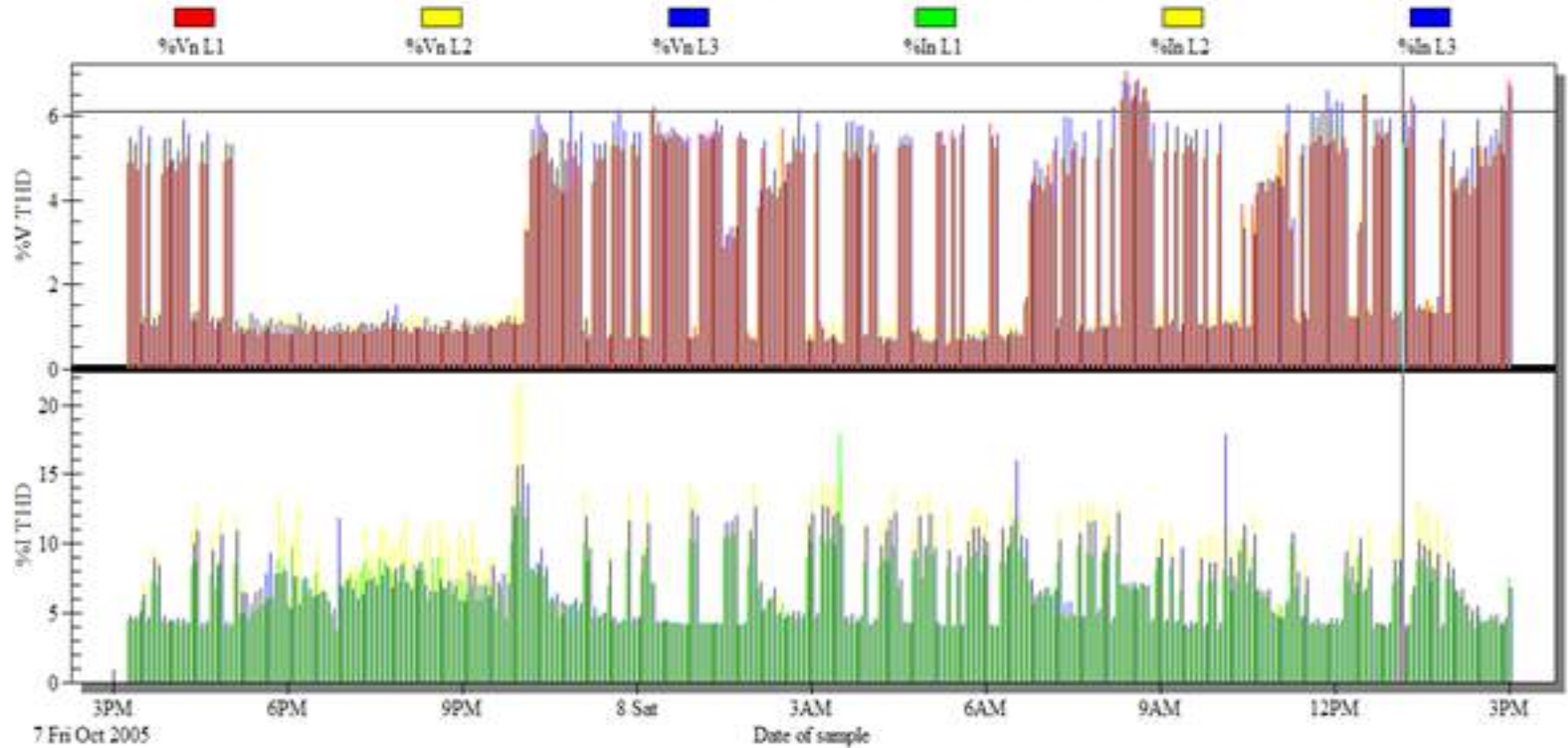
Selected Variable: INCOMER-1.A5I (Current: Phase III)

Act : 08-Oct-05 13:10:00
Act : 215.875 (A)

From : 07-Oct-05 15:15:00
Maximum : 215.875 (A)

To : 08-Oct-05 22:29:54
Minimum : 0.000 (A)

TOTAL HARMONIC DISTORSION OF INCOMER-1



Act: 08-Oct-05 13:10:00
Act: 6.1 (%V THD)

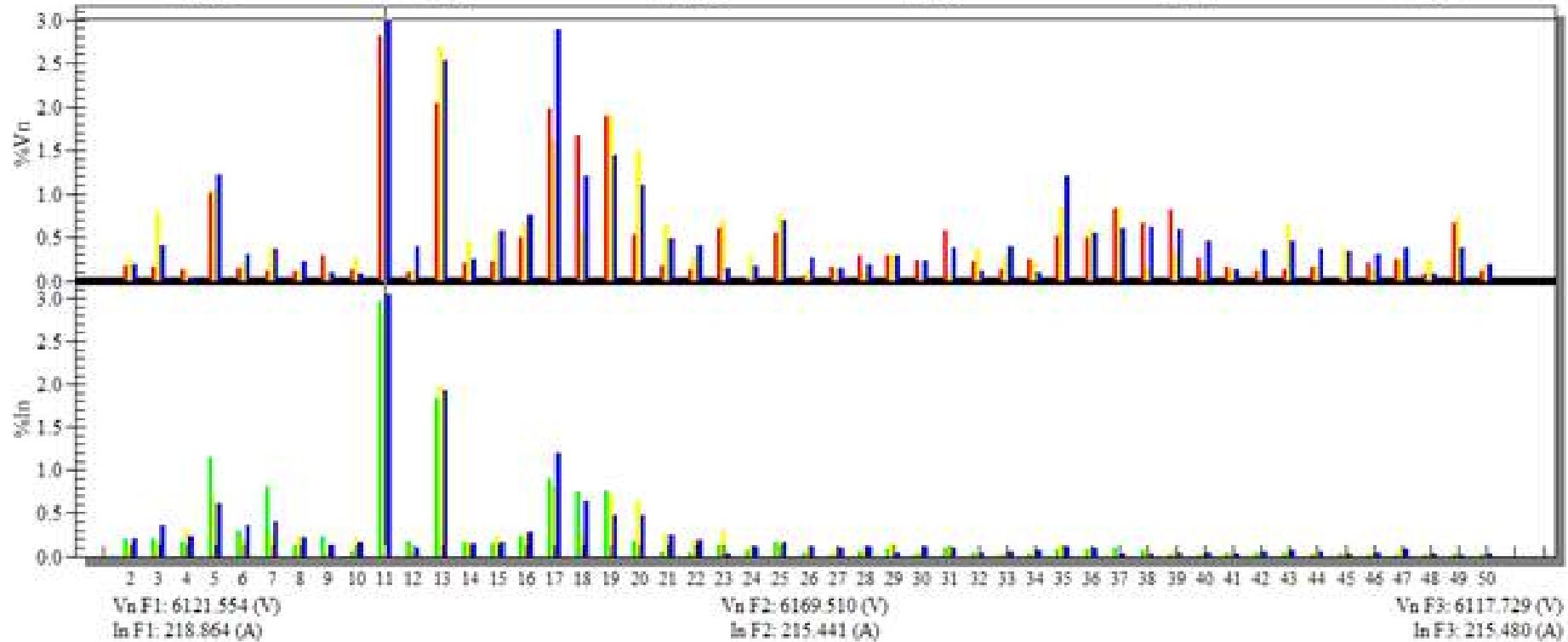
Selected Variable: %Vn L3
From: 07-Oct-05 15:15:00
Maximum: 6.9 (%V THD)

To: 08-Oct-05 22:29:54
Minimum: 0.0 (%V THD)

INDIVIDUAL HARMONICS OF INCOMER-1

08-Oct-05 13:10:00

%Vn L1 %Vn L2 %Vn L3 %In L1 %In L2 %In L3



Act: 11
Act: 3.015 (%Vn)

Selected Variable: %Vn L3
From: 2
Maximum: 3.015 (%Vn)

To: 50
Minimum: 0.032 (%Vn)

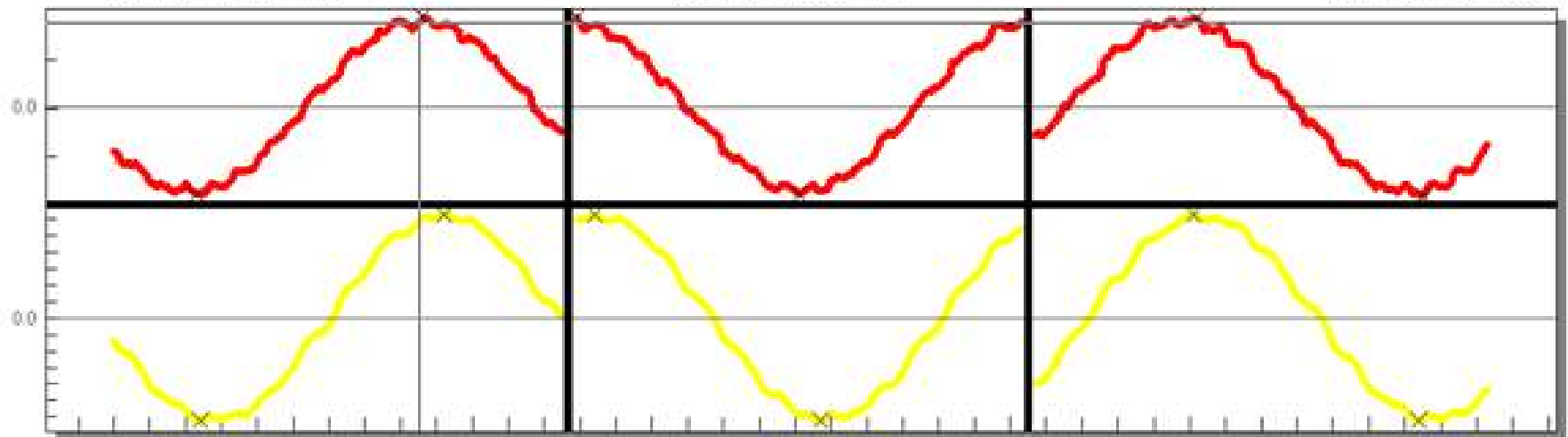
WAVE FORM OF INCOMER-1

08-Oct-05 13:10:00

Vn F1: 6122 (V)
THD: 5.3 %
Maximum: 9000 (V)
Minimum: -8900 (V)

Vn F2: 6170 (V)
THD: 5.5 %
Maximum: 9300 (V)
Minimum: -9100 (V)

Vn F3: 6118 (V)
THD: 6.1 %
Maximum: 8900 (V)
Minimum: -9000 (V)



In F1: 218.864 (A)
THD: 4.1 %
Maximum: 311.640 (A)
Minimum: -310.800 (A)

In F2: 215.441 (A)
THD: 3.8 %
Maximum: 309.000 (A)
Minimum: -309.000 (A)

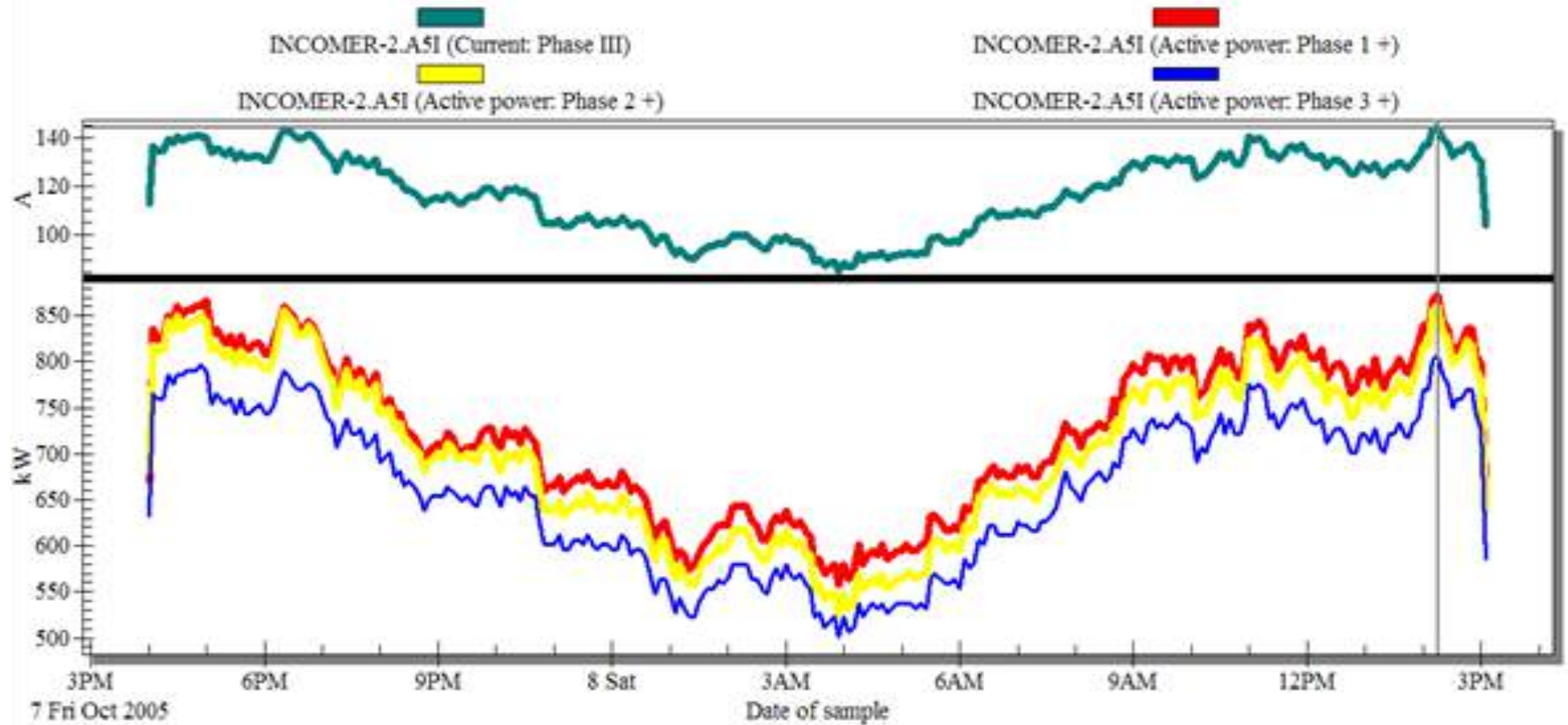
In F3: 215.480 (A)
THD: 4.1 %
Maximum: 310.440 (A)
Minimum: -307.200 (A)

Act : 8500 (V)

Maximum : 9000 (V)

Minimum : -8900 (V)

GRAPH OF INCOMER-2 POWER AND CURRENT DETAILS



Selected Variable: INCOMER-2.A5I (Current: Phase III)

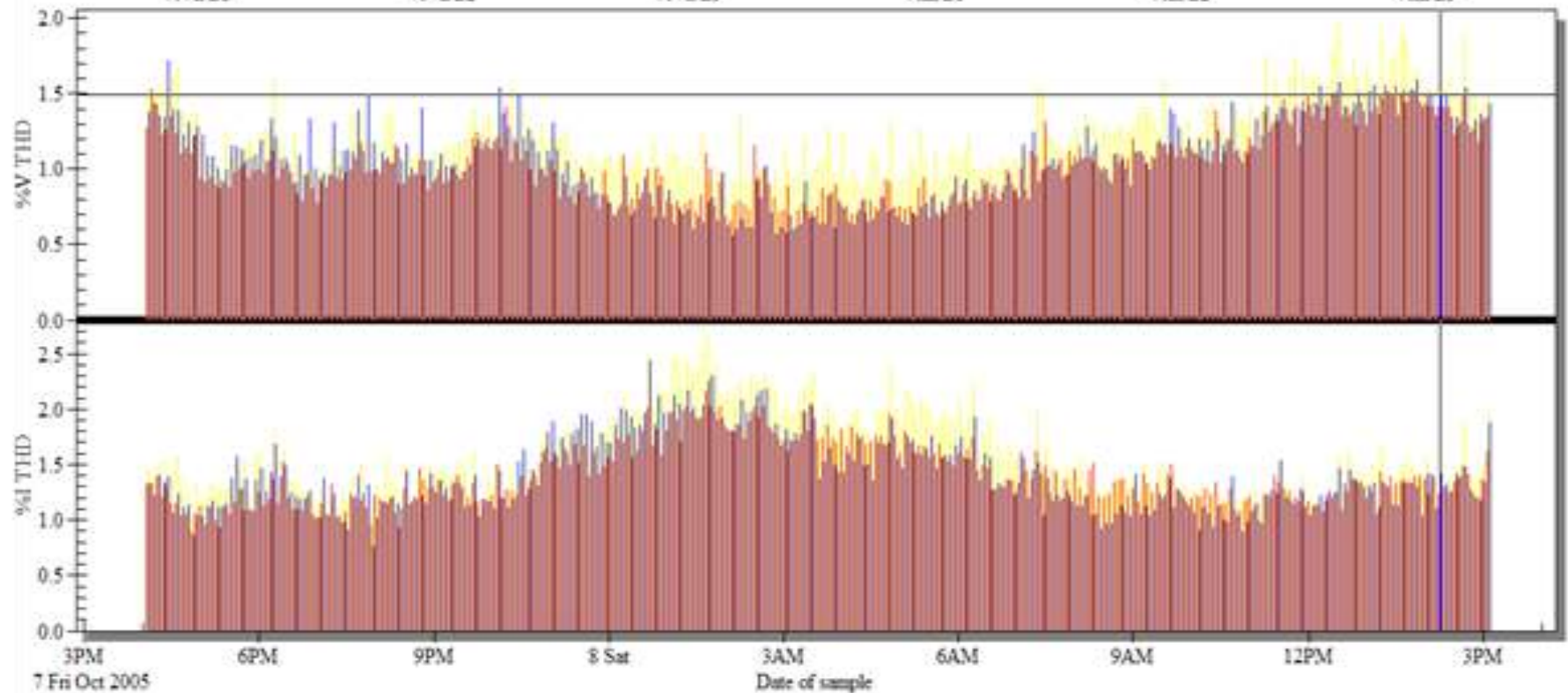
Act : 08-Oct-05 14:15:00
Act : 144.505 (A)

From : 07-Oct-05 16:00:29
Maximum : 144.505 (A)

To : 08-Oct-05 15:05:00
Minimum : 85.264 (A)

TOTAL HARMONIC DISTORSION OF INCOMER-2

■ %Vn L1
 ■ %Vn L2
 ■ %Vn L3
 ■ %In L1
 ■ %In L2
 ■ %In L3



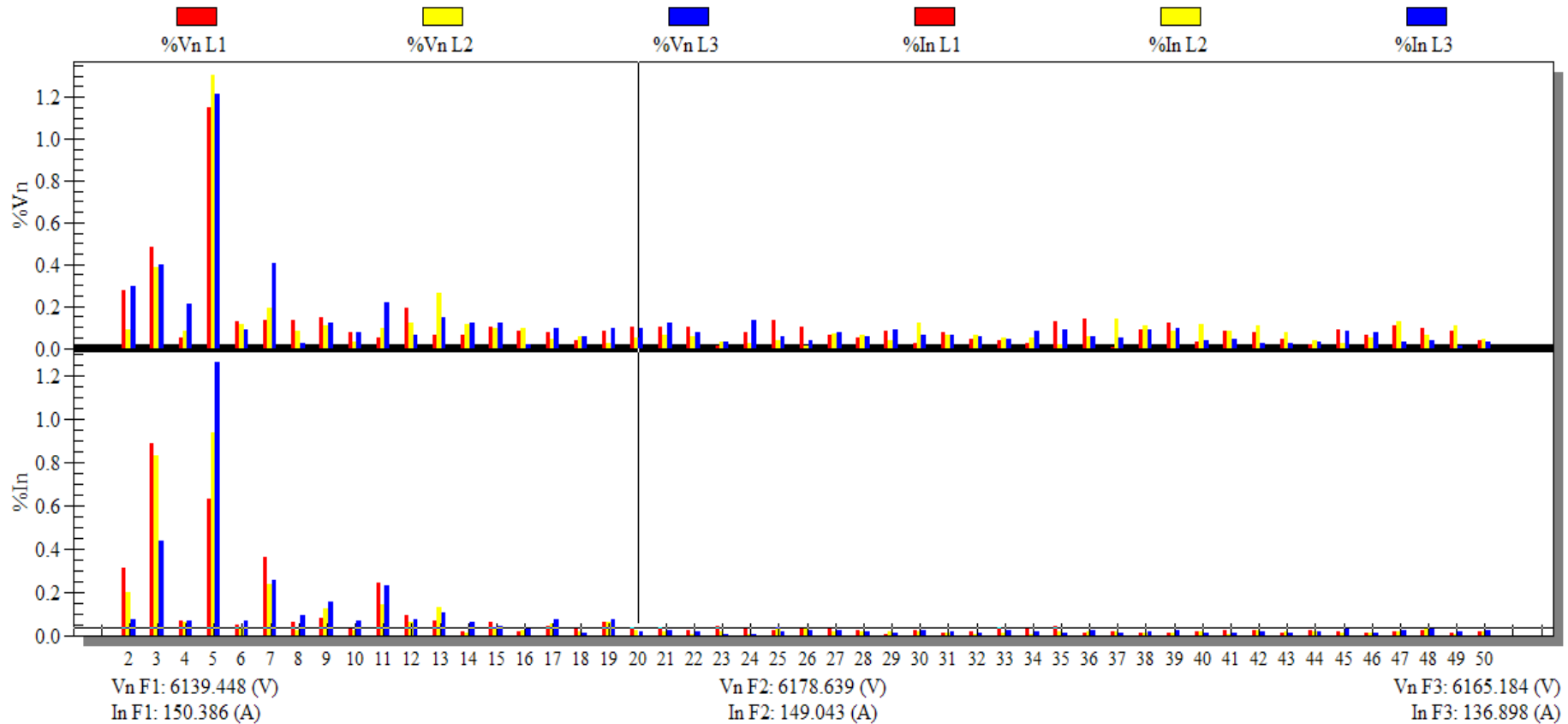
Act: 08-Oct-05 14:15:00
Act: 1.5 (%V THD)

Selected Variable: %Vn L2
From: 07-Oct-05 16:00:29
Maximum: 2.0 (%V THD)

To: 08-Oct-05 15:05:00
Minimum: 0.0 (%V THD)

INDIVIDUAL HARMONICS OF INCOMER-2

08-Oct-05 14:15:00



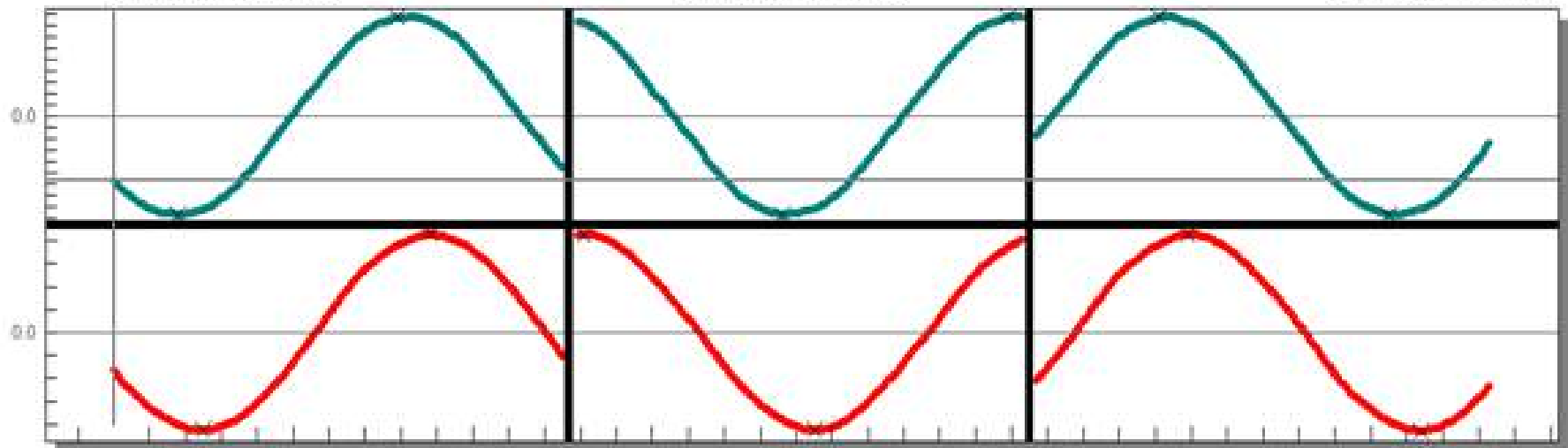
WAVE FORM OF INCOMER-2

08-Oct-05 14:15:00

Vn F1: 6139 (V)
THD: 1.4 %
Maximum: 8600 (V)
Minimum: -8600 (V)

Vn F2: 6179 (V)
THD: 1.5 %
Maximum: 8700 (V)
Minimum: -8700 (V)

Vn F3: 6165 (V)
THD: 1.5 %
Maximum: 8700 (V)
Minimum: -8700 (V)



In F1: 150.386 (A)
THD: 1.2 %
Maximum: 213.240 (A)
Minimum: -212.760 (A)

In F2: 149.043 (A)
THD: 1.3 %
Maximum: 213.960 (A)
Minimum: -213.960 (A)

In F3: 136.898 (A)
THD: 1.4 %
Maximum: 194.400 (A)
Minimum: -195.360 (A)

Act : -5600 (V)

Maximum : 8600 (V)

Minimum : -8600 (V)



Thank you