

<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 1 of 39

Harmonic Measurement Survey Report

at

Howard Street

Report prepared by:

S Joyce

Power Quality Area Engineer

ABB Ltd

Rossmore Road East

Ellesmere Port

Wirral

CH65 3DD

Tel 0151 357 8400

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Terminology

A number of standards, terms and abbreviations are used to compile this report; the full descriptions are detailed below.

Term/abbreviation	Description
BS-EN 50160:2000	Voltage Characteristics of Electricity Supplied by Public Distribution Systems.
BS-EN 61000-4-7:2002	Electromagnetic Compatibility (EMC) General Guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto
IEC 61000-4-30:2003	Electromagnetic Compatibility (EMC) Testing and measurement techniques – Power quality measurement methods
G5/4-1	Energy Networks Association Engineering Recommendation G5/4-1 Dated October 2005“Planning Levels for Harmonic Voltage Distortion and the Connection of Non-Linear Equipment to Transmission Systems and Distribution Networks in the United Kingdom.”
ETR 122	Energy Networks Association Engineering Technical Report ETR122 Dated February 2003 “Guide to the Application of Engineering Recommendation G5/4 in the Assessment of Harmonic Voltage Distortion and Connection of Non-Linear Equipment to the Electricity Supply System in the UK.
EMC	Electromagnetic Compatibility – harmonics are low frequency conducted emissions.
Fault Level	The power that will flow in a short circuit condition in a network, this gives a guide to the network impedance.
Harmonic	The harmonic components in a line voltage or current when subjected to a fourier analysis. Principle harmonics in the public supply network are odd integers and are measured up to the 50 th .
NOC	Network Operating Company (the electricity supply company who provide the connection to the network, not necessarily the clients electricity vendor)
MCC	Motor Control Centre
PCC	Point of Common Coupling – the point at which other consumers are connected to the public electricity supply

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Harmonic Theory

Basics

Many modern electrical and electronic products incorporate rectifiers, which take a non-linear current from the power supply.

There are a number of different methods of rectification that can be considered, the most common are uncontrolled (a number of diodes connected in a bridge), controlled (a number of thyristors connected in a bridge), and active (a number of IGBTs connected in a bridge).

These currents take the form of repetitive waveforms that can be subject to a fourier analysis to determine the magnitude and angle of each harmonic component. Each type of device will produce a characteristic harmonic spectrum, which will vary with bridge design, levels of filtering and source impedance. As the current will be drawn through the impedance of the supply network it will generate a complementary voltage distortion spectrum.

Typical effects of harmonics are detailed in the table below:-

Effects of high harmonic currents

- Overheating of conductors
- Insulation failure
- Nuisance tripping of circuit breakers
- Nuisance rupturing of fuses
- Additional significant voltage distortion of networks run from generators
- Overheating and possible resonance on networks using capacitors

- Overloaded neutral
- Neutral earth potential
(generally due to single phase harmonic loads)

- PC/TV monitor stroboscopic effects
- Malfunction of microprocessor based equipment

Effects of high harmonic voltage distortion

- Causes linear devices to draw non linear current (ie- motors)
- Torque pulsations in motors
- Flicker in lighting
- Capacitor di-electric failure
- Insulation breakdown
- PC/TV monitor and power supply failure
- Electronic lighting failure

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Current Distortion

Both single and three phase non-linear loads draw harmonic currents. For both controlled and uncontrolled rectifiers the dominant harmonic is generally denoted by n-1, where n is the number of rectifying devices, ie a single phase 4 diode rectifier gives a dominant 3rd. harmonic, and a three phase 6 diode rectifier gives a dominant 5th, harmonic.

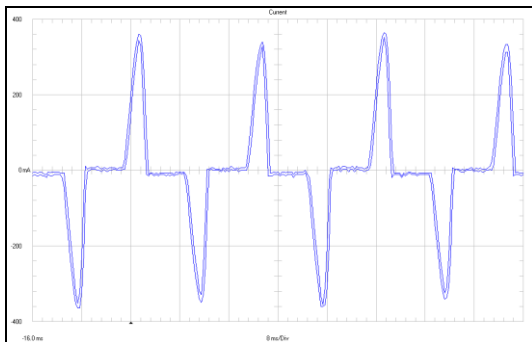


Figure 1

Typical measured current waveform for single phase uncontrolled rectifier

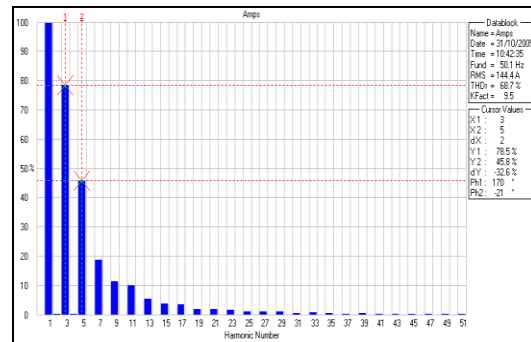


Figure 2

Typical measured harmonic current spectrum for single phase uncontrolled rectifier

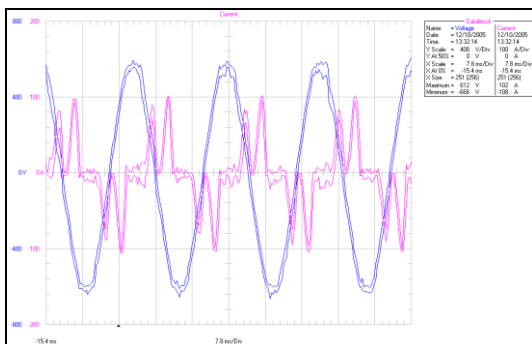


Figure 3

Typical current and voltage waveform for 6 pulse uncontrolled rectifier

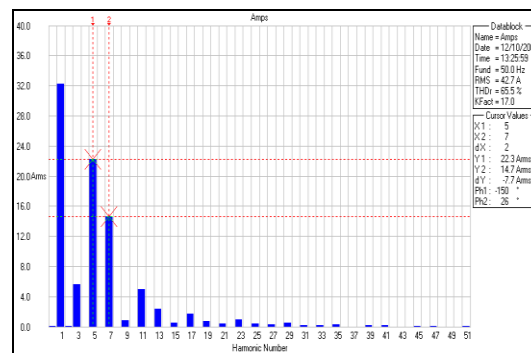


Figure 4

Typical current spectrum analysis for 6 pulse uncontrolled rectifier

Voltage Distortion

Voltage distortion propagates throughout the entire distribution network, and must be regulated by the distributor to avoid the damaging effects.

The magnitude of the distortion is dependent on the current and the network impedance, and the lower the network impedance (higher fault level), the lower the resultant voltage distortion.

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The levels of acceptable distortion are laid down in a number of standards including EN 50160, and IEC 61000 series.

Harmonic flow

In theory a current will flow to the lowest impedance, hence it would be expected that harmonic current flow would be up through the increasing voltage levels of the network, however, if there are any resonant components in a network at lower voltage level, such as power factor correction, there can be a flow in this direction.

Limits for Harmonic Voltage & Current

In the UK the network operators are governed by statutory instruments which specify the levels of service and network power quality and forms part of their license agreement.

Part of the power quality requirements are incorporated in an installation standard known as the Energy Networks Association Engineering Recommendation G5/4-1 – Planning levels for harmonic voltage distortion and connection of non-linear equipment to transmission systems and distribution networks in the UK.

This gives a number of Stages that can be applied to connections for consumers, and a guide to its application is available from www.gambica.org.uk.

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Introduction

The objective of the survey is to carry out a power quality survey at Howard Street.

Measurements were made for 5 days from 22/03/2012 12:20:12.0 to 26/03/2012 17:28:54.0

Site Data

The site is located at main incomer.

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Basic Data

1.	Company (submitting the report)	ENW
2.	Contact Name and Address	Gavin Anderson Tel: +44 (0) 161 604 1380
3.	Site address	Howard Street
4.	Metering Point Account Number	N/A
5.	Network connection (where known)	N/A
6.	Transformer details (where relevant)	N/A
7.	Reason for the survey	Power Quality Survey
8.	Existing non linear load	Non-Linear Load
9.	Details of new non linear load	N/A
10.	Point of measurement	415V Main Incomer
11.	Measurements	Power Quality
12.	Connection Arrangements	4 WIRE / 3 PROBE (WYE)
13.	Measuring instrument	Dranetz PX5
14.	Start time for measurements	22/03/2012 12:20:12.0
15.	Finish time for measurements	26/03/2012 17:28:54.0

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Instrument Configuration

Firmware	Power Xplorer (c) 2009 Dranetz-BMI Oct 14 2010 @ 11:37:27 Ver.: V 4.2, Build: 7, DB ver.: 0
Serial Number	PX50AA150
Site/Filename	HOWARD STREET
Measured from	22/03/2012 12:20:08
Measured to	26/03/2012 17:28:55
File ending	OK
Synchronization	Standard A
Configuration	4 WIRE / 3 PROBE (WYE)
Monitoring type	STANDARD PQ
Nominal voltage	240.0 V
Nominal current	29.5 A
Nominal frequency	50.0 Hz
Use inverse sequence	No
Using currents	Yes
Characterizer mode	IEEE 1159

Current probes

Chan A	RR3035 (Range2), 300A (Scale=100.00)
Chan B	RR3035 (Range2), 300A (Scale=100.00)
Chan C	RR3035 (Range2), 300A (Scale=100.00)
Chan D	Other (Scale=1.00)

Voltage scale factors

Chan A	1.000
Chan B	1.000
Chan C	1.000
Chan D	1.000

Current scale factors

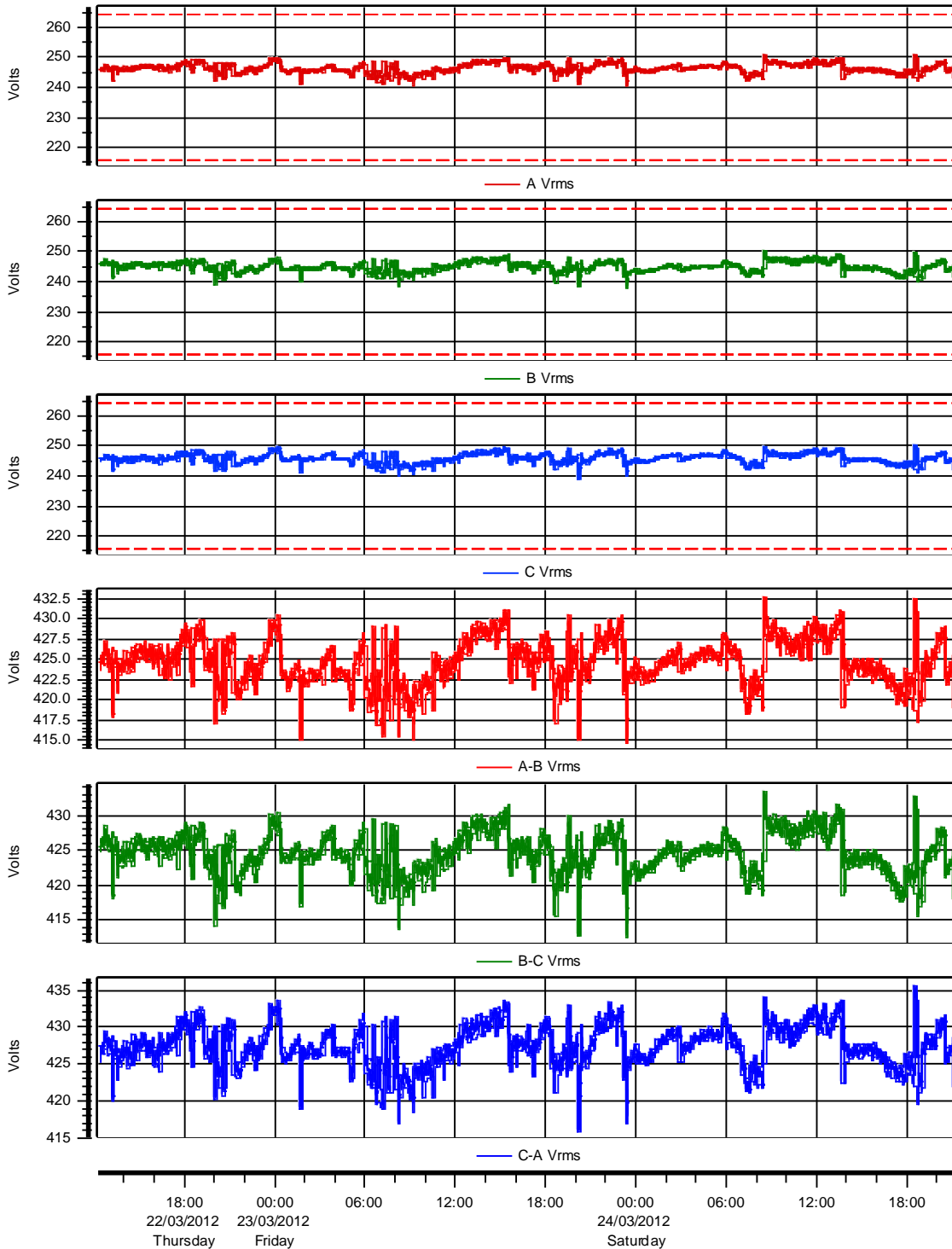
Chan A	1.000
Chan B	1.000
Chan C	1.000
Chan D	1.000

Trigger Response Setups

Summary Pre-trigger cycles	6 cycles
Summary Post-trigger cycles IN-TO-OUT	6 cycles
Summary Post-trigger cycles OUT-TO-IN	6 cycles
Waveform Pre-trigger cycles	1 cycles
Waveform Post-trigger cycles	2 cycles

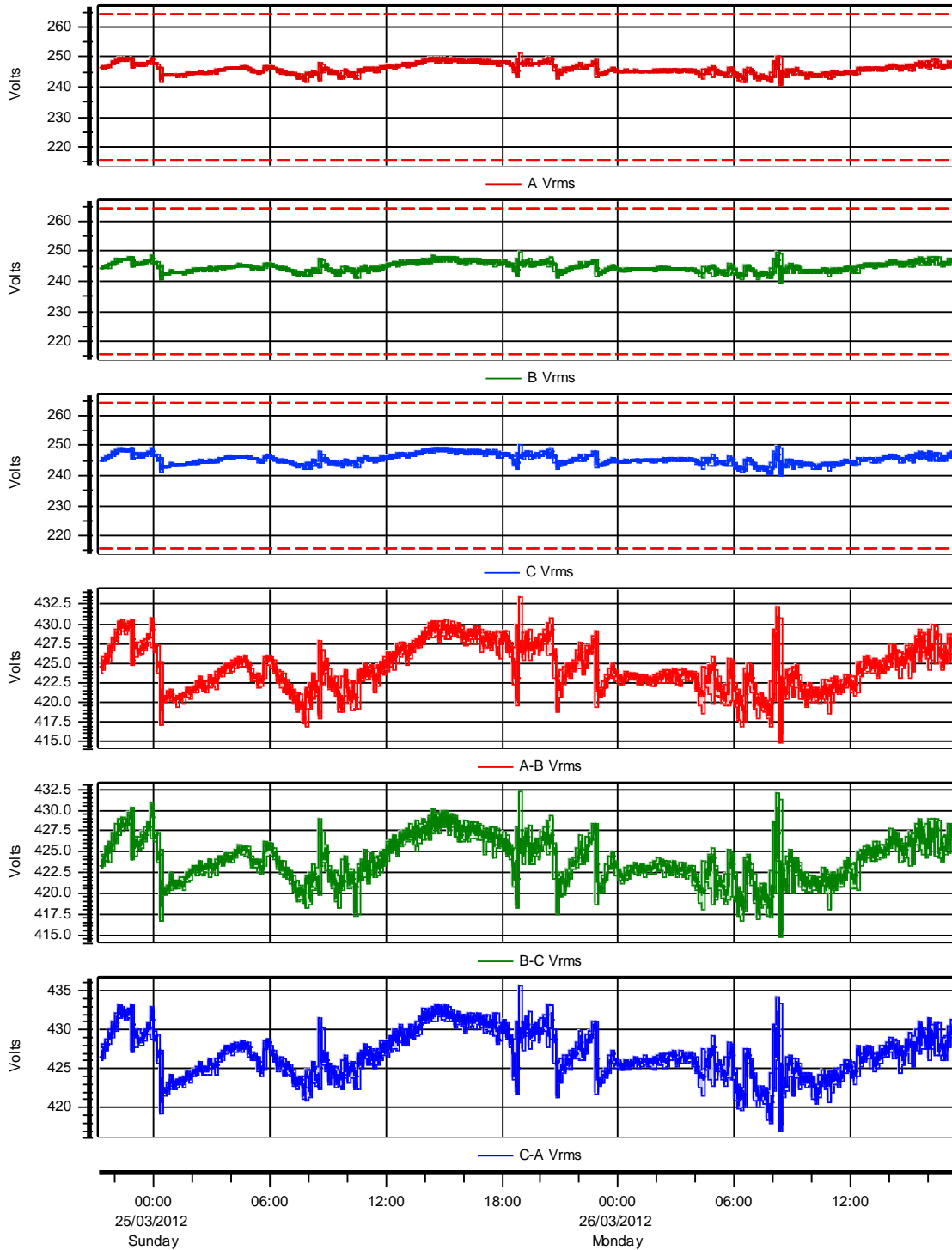
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Timeplot
Voltage RMS value



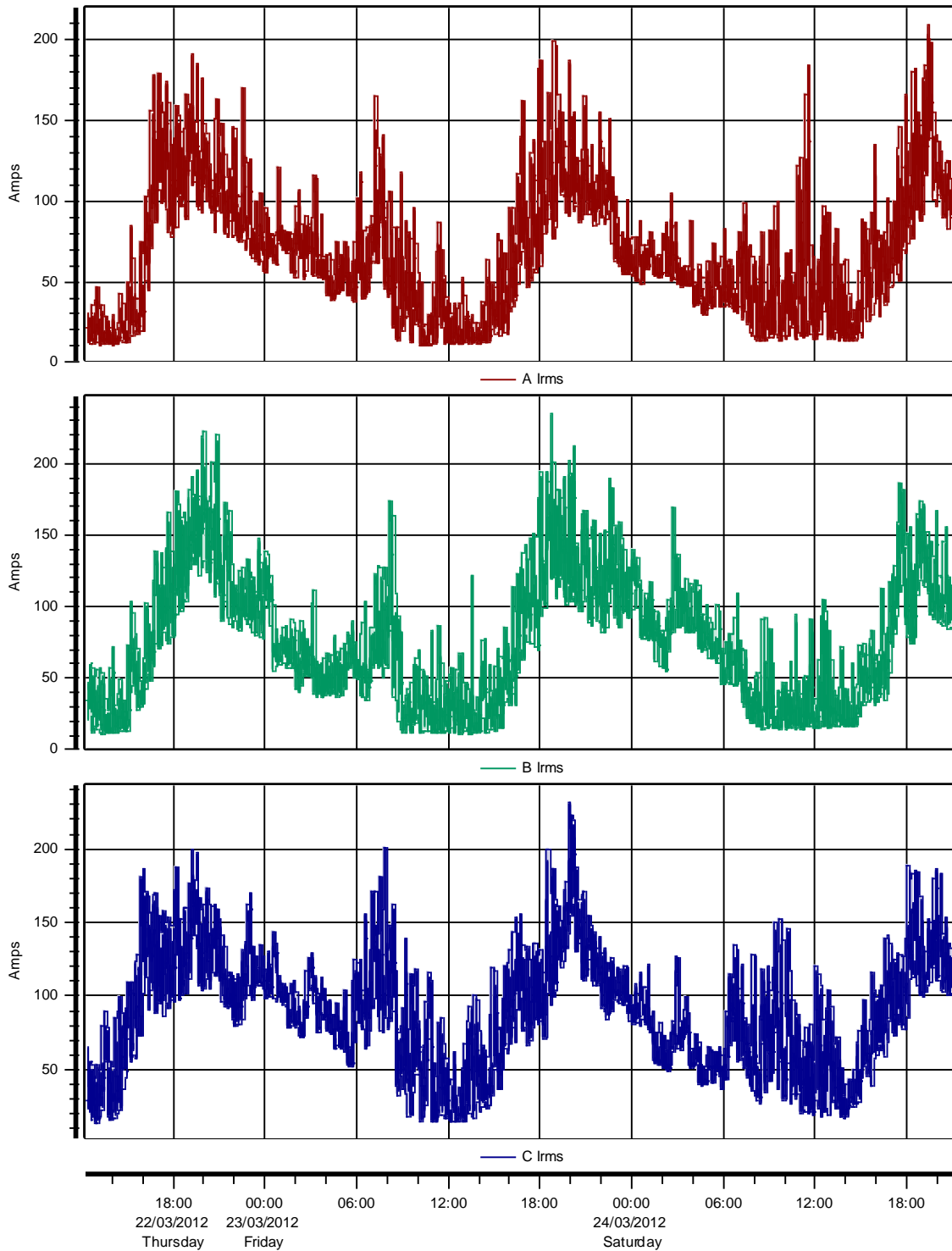
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Timeplot
Voltage RMS value



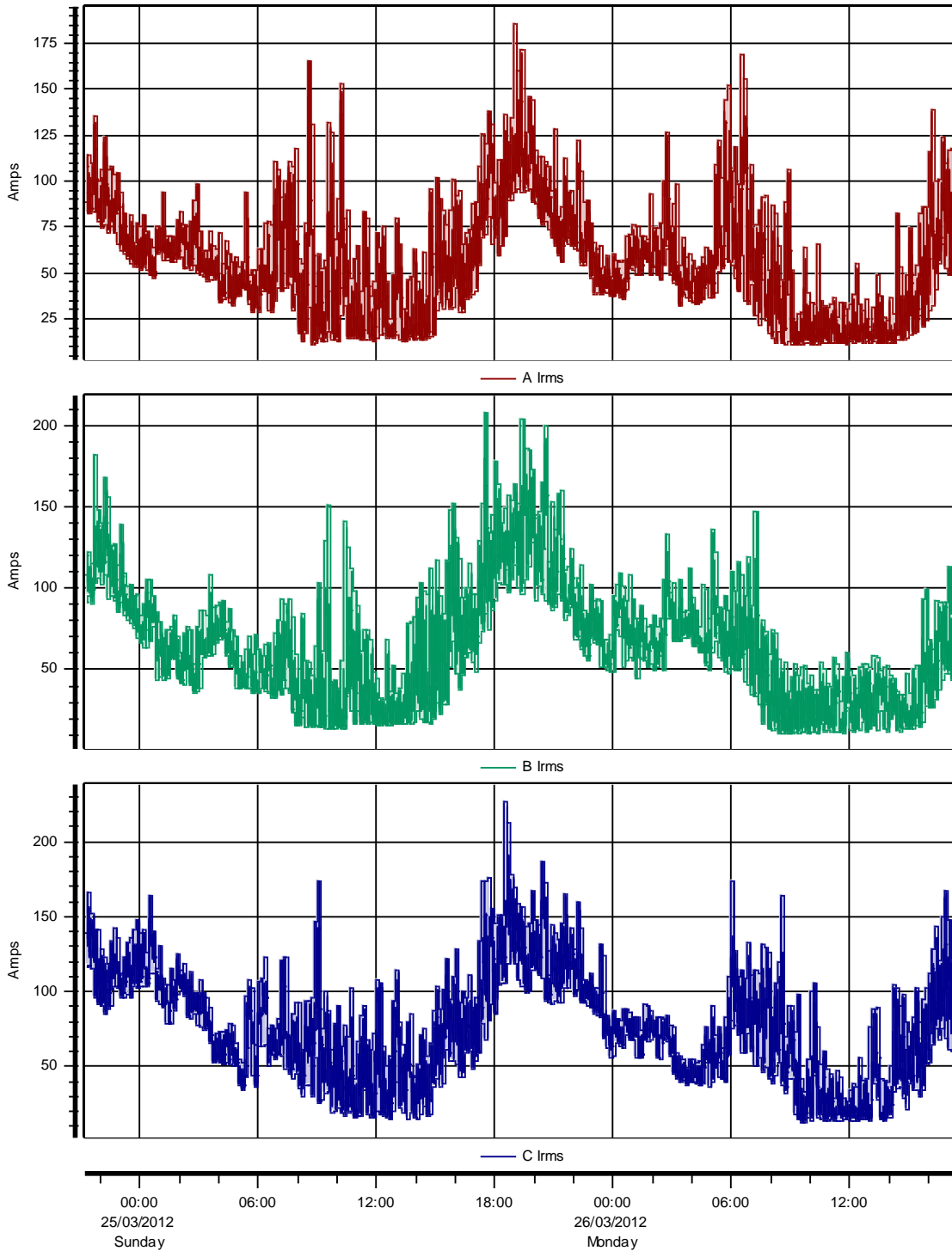
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Timeplot
Current RMS value



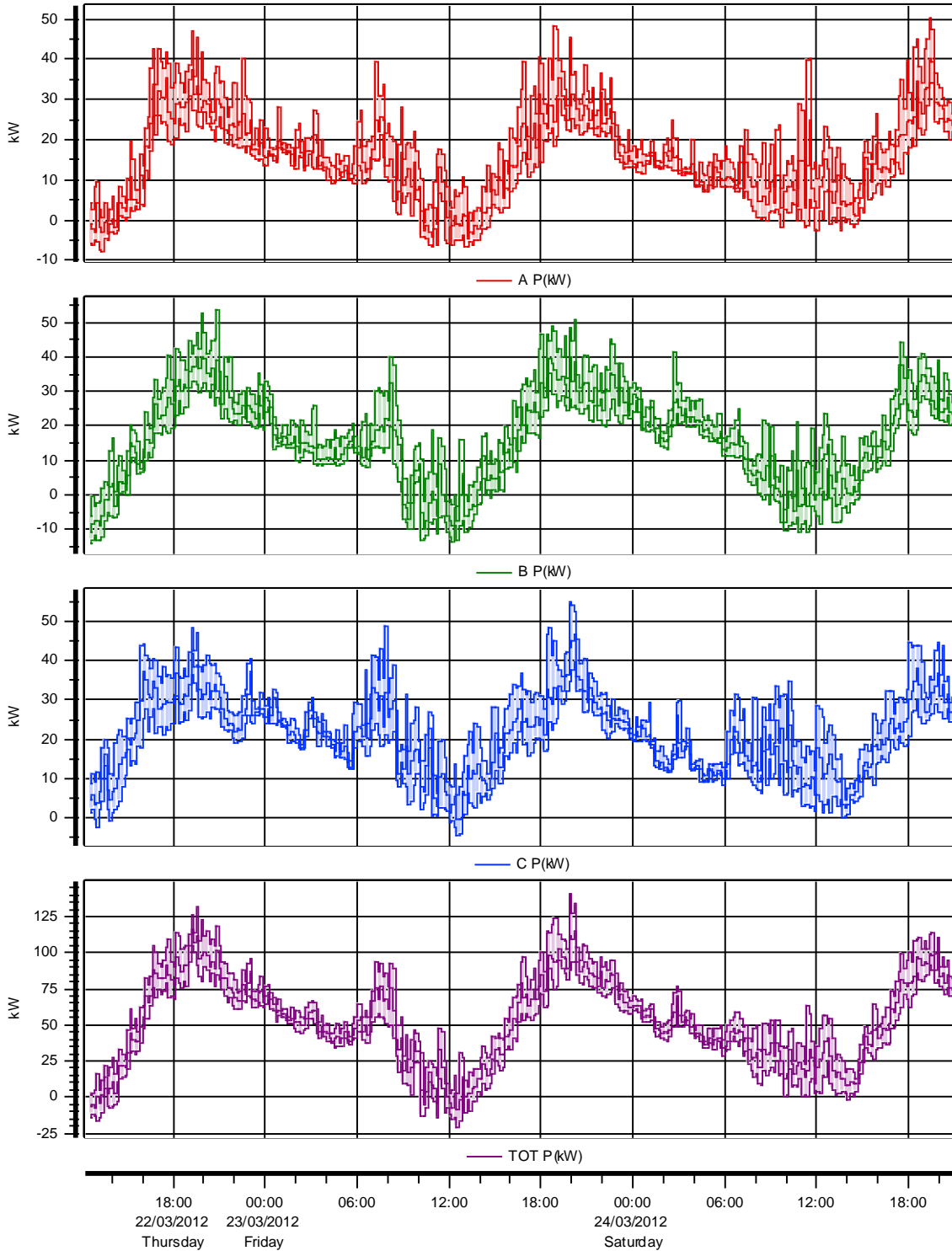
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Timeplot
Current RMS value



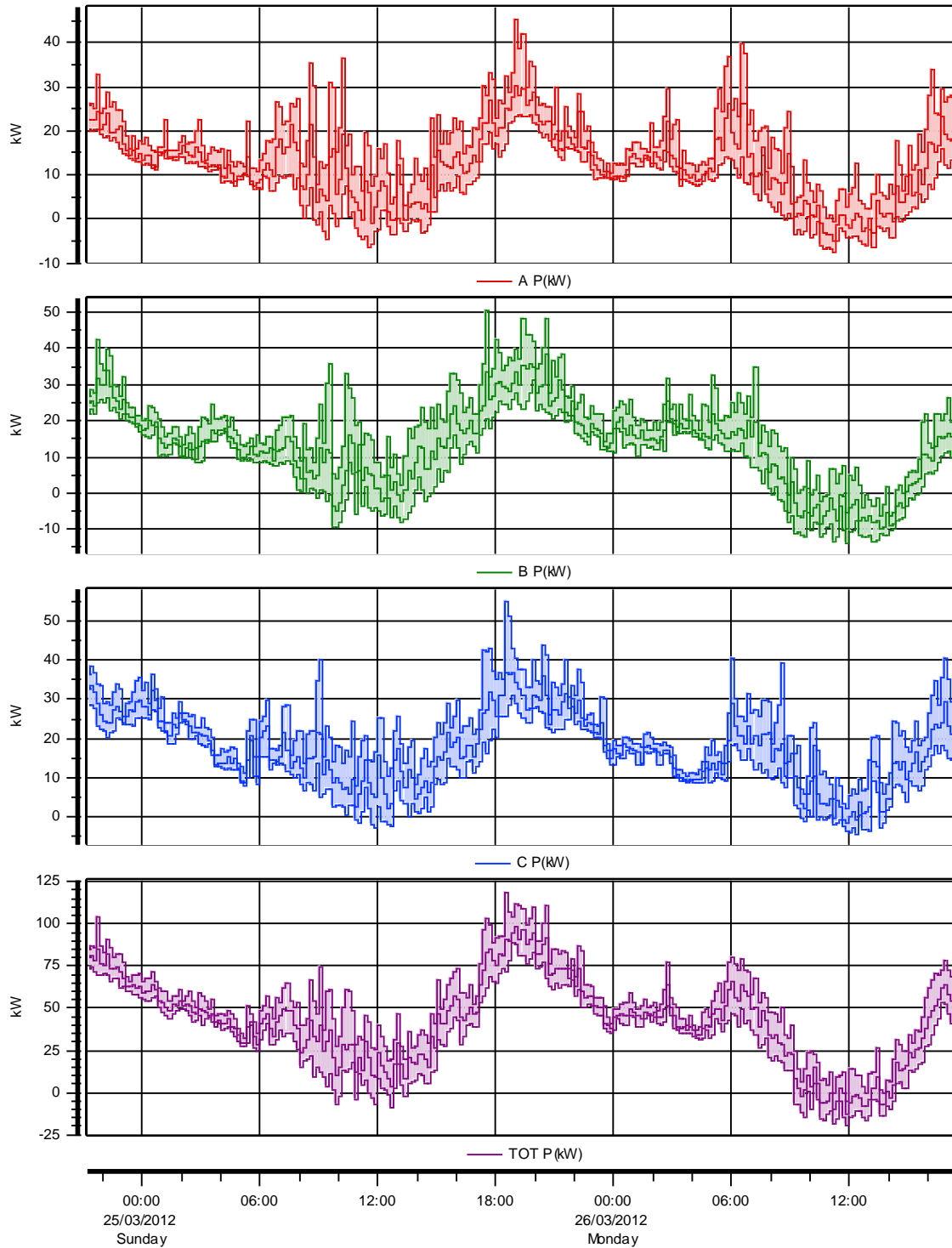
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Timeplot
Active power, P (W)



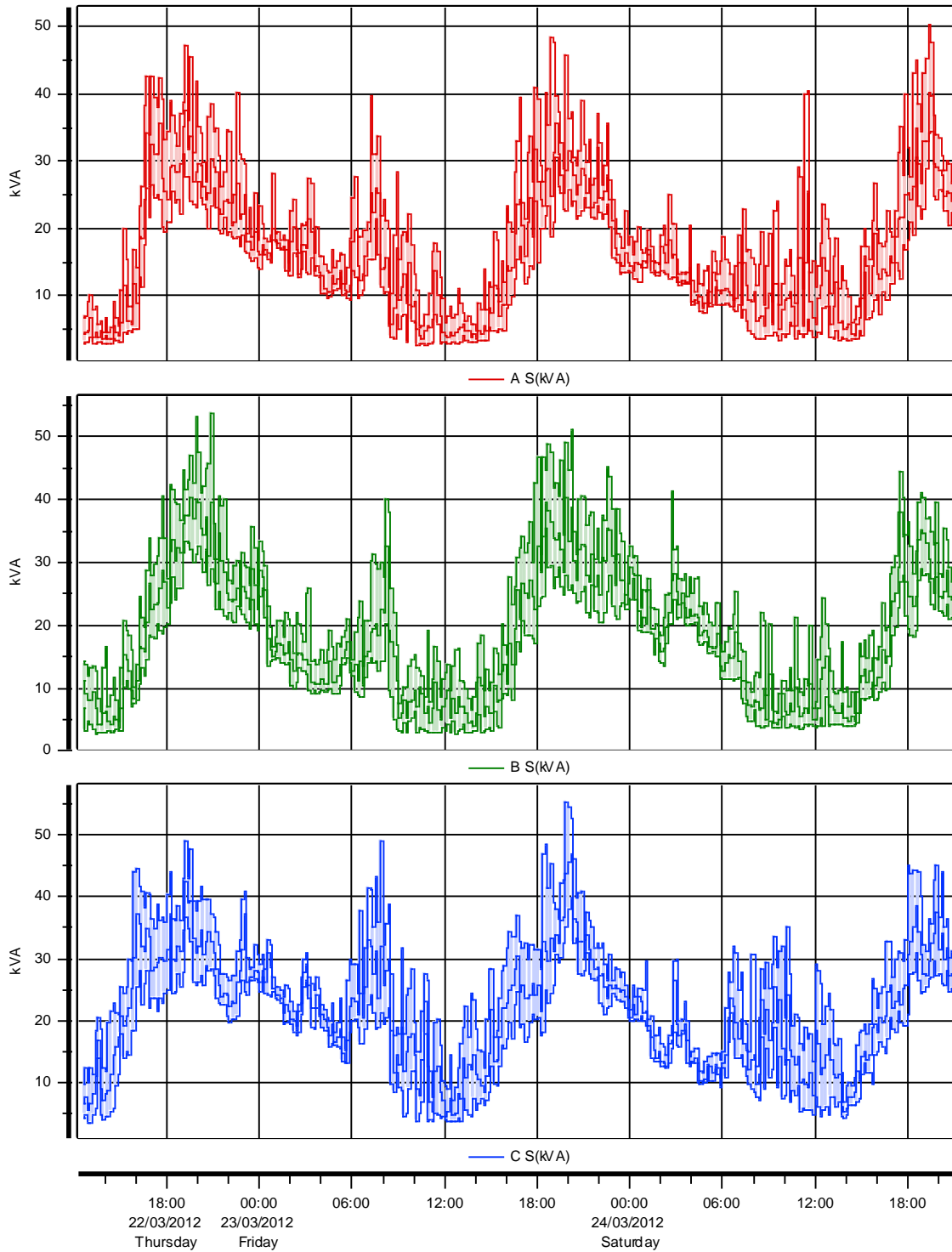
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Timeplot
Active power, P (W)



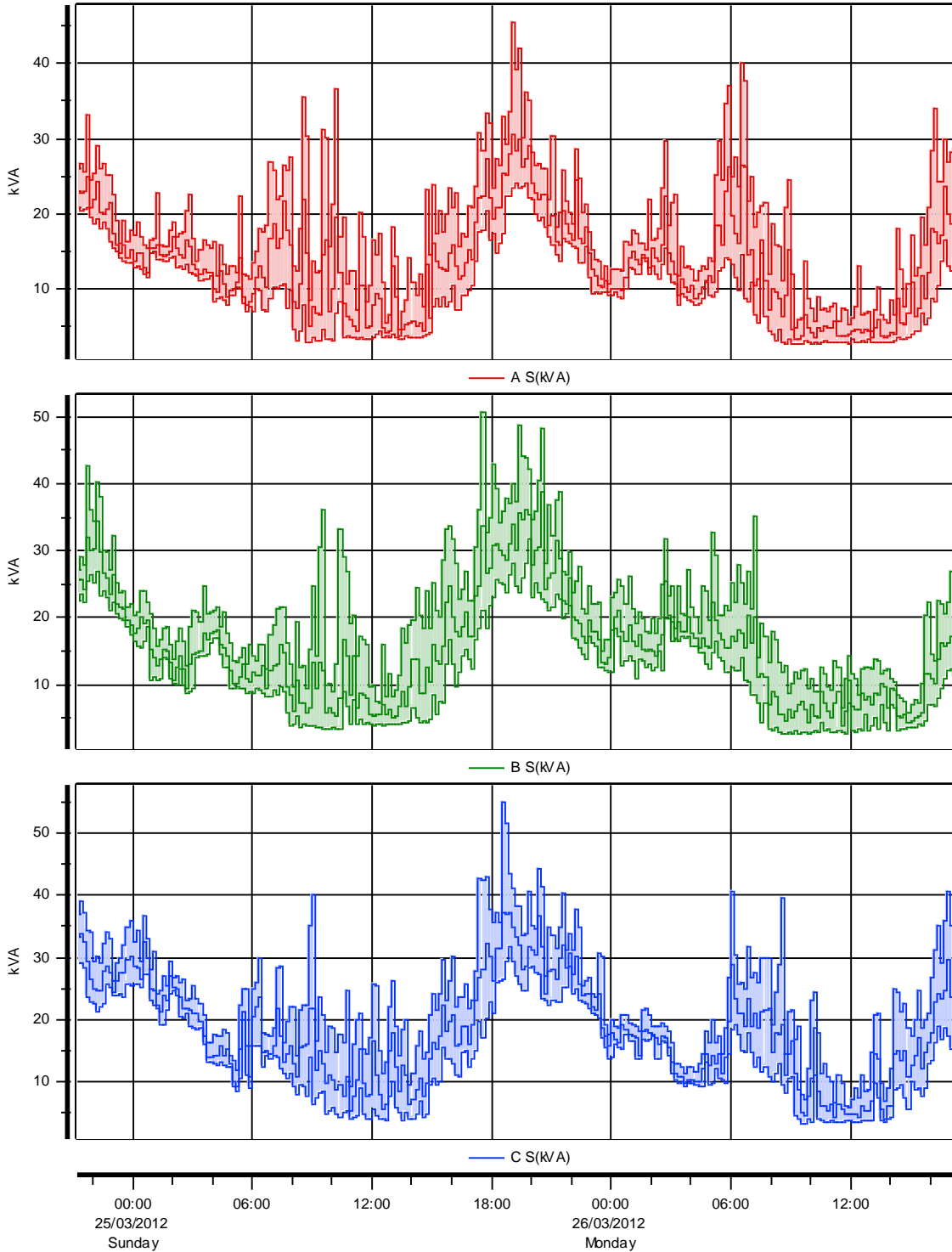
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Timeplot
Apparent power, S (VA)



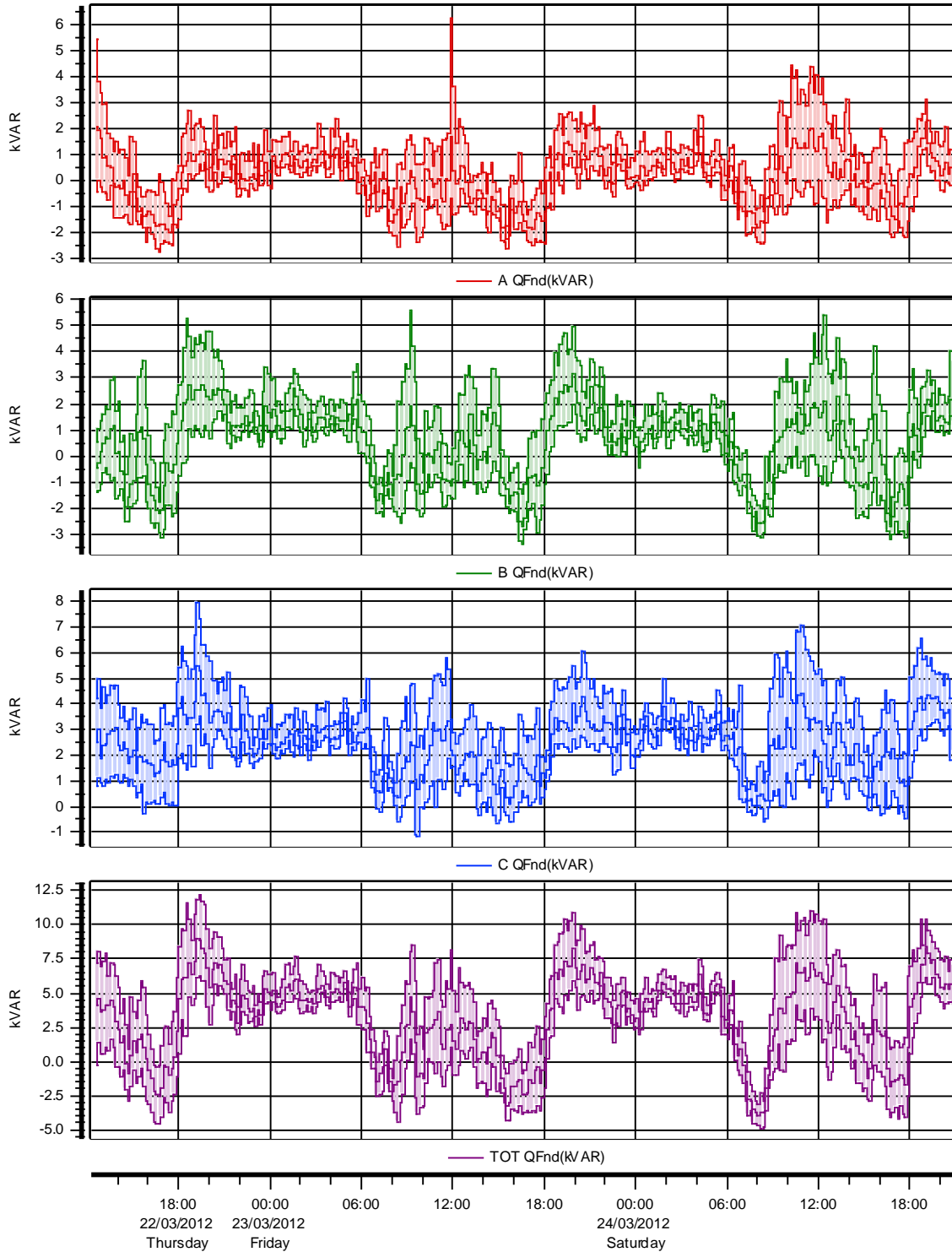
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Timeplot
Apparent power, S (VA)



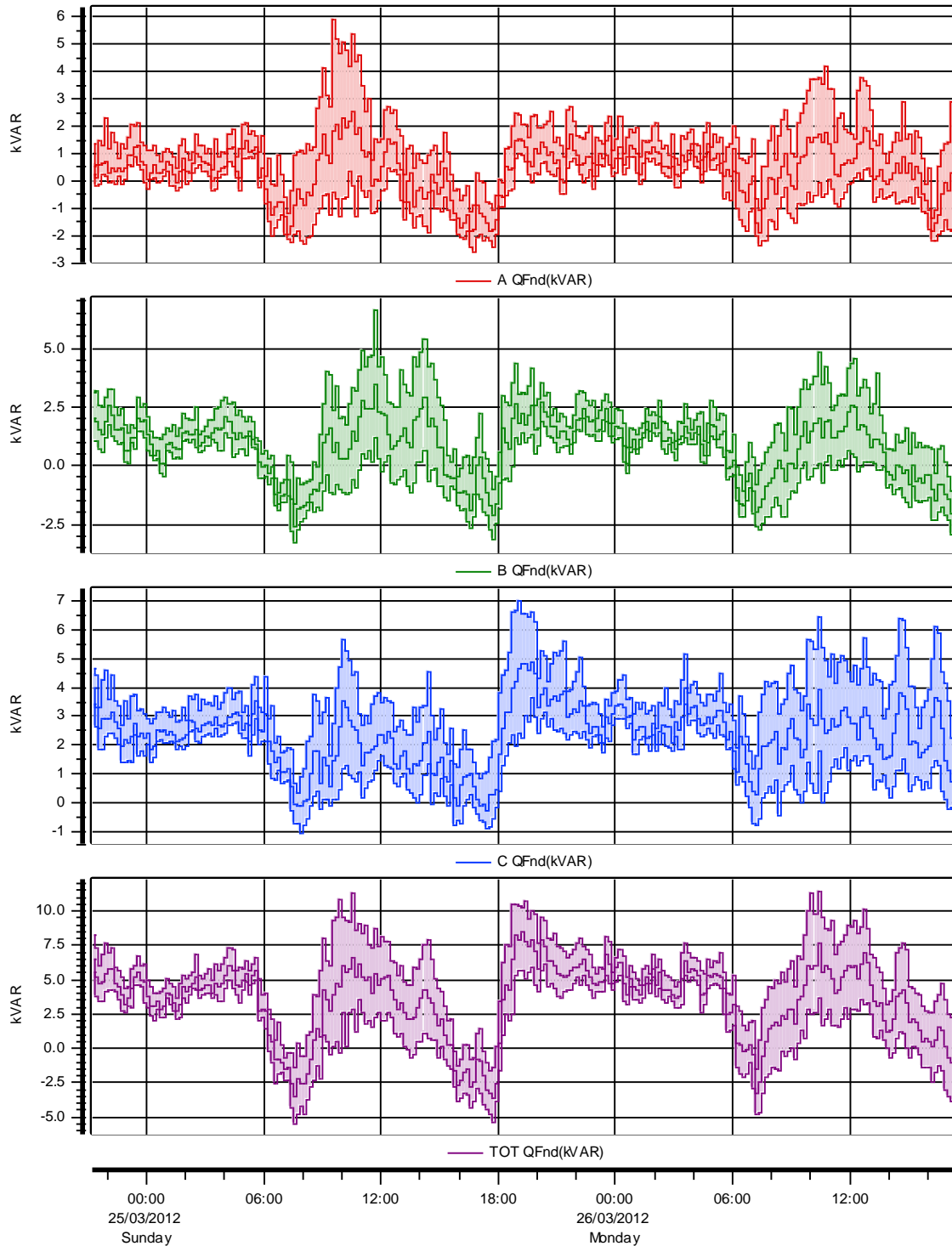
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Timeplot
Reactive power Q, at fund. freq. (VAR)

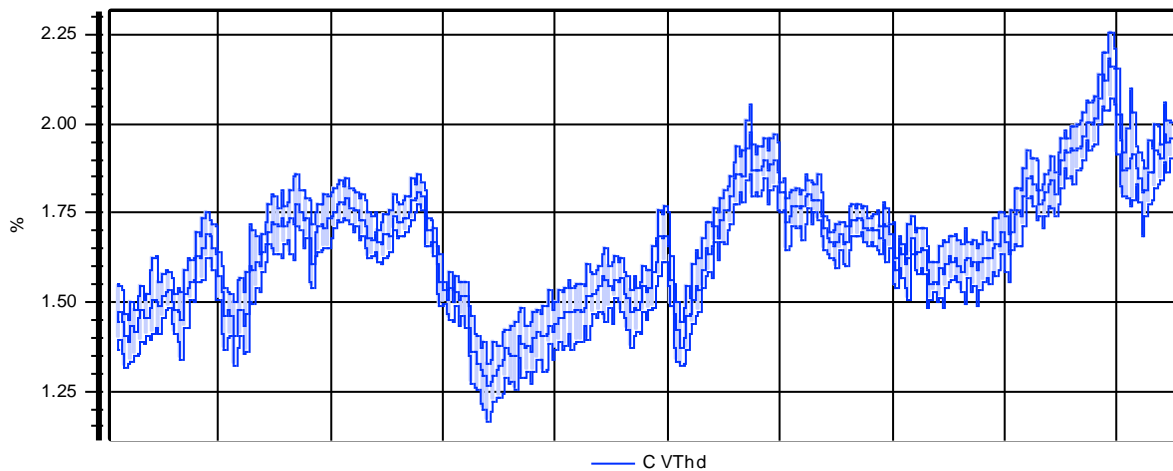
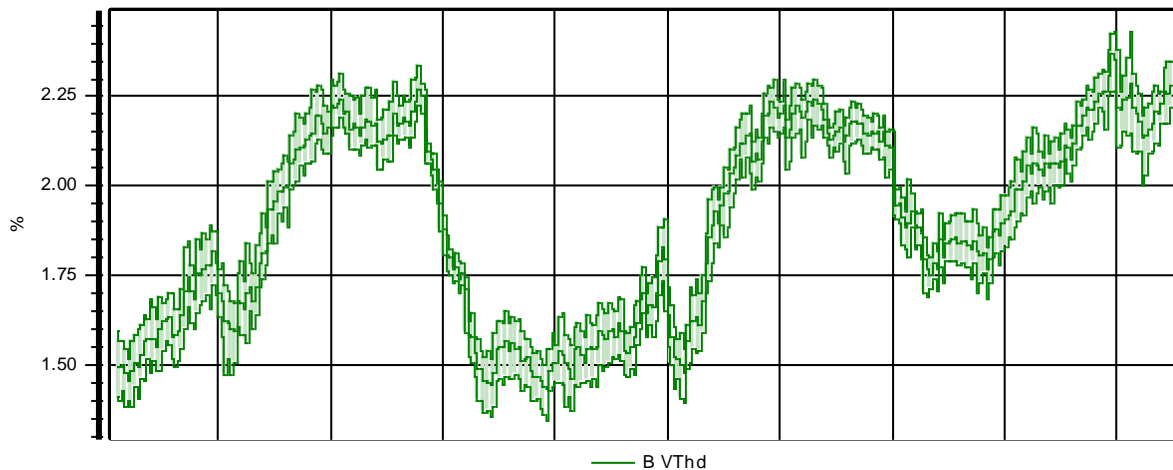
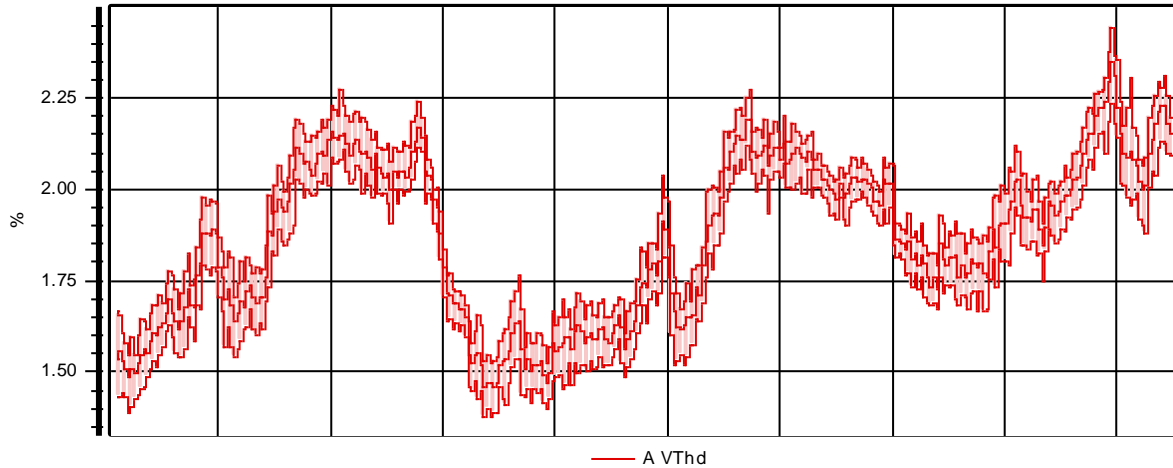


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Timeplot
Reactive power Q, at fund. freq. (VAR)



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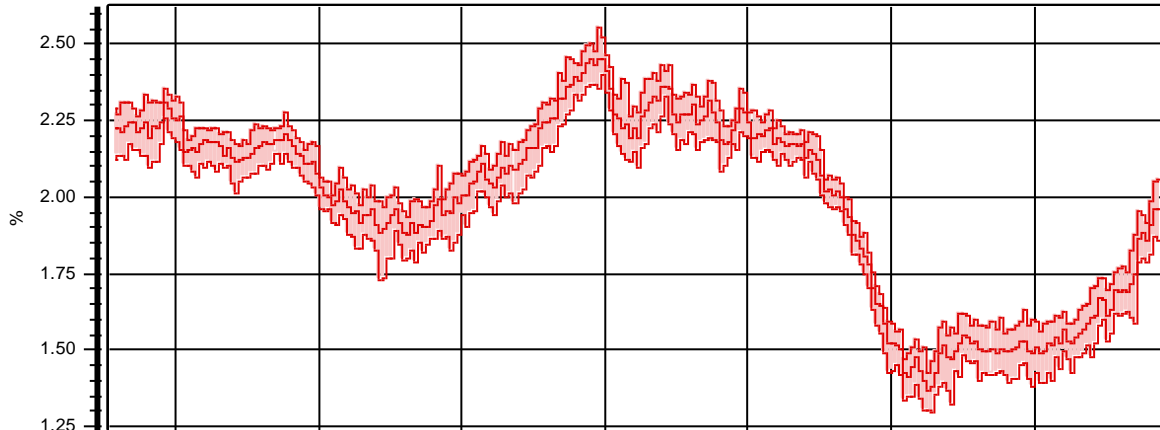


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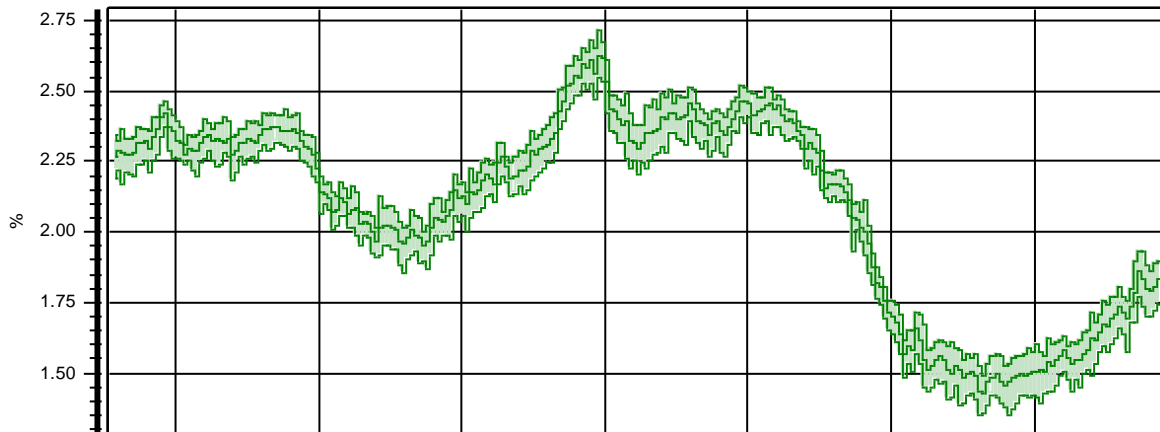
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23/03/2012
24/03/2012

Thursday
Friday
Saturday

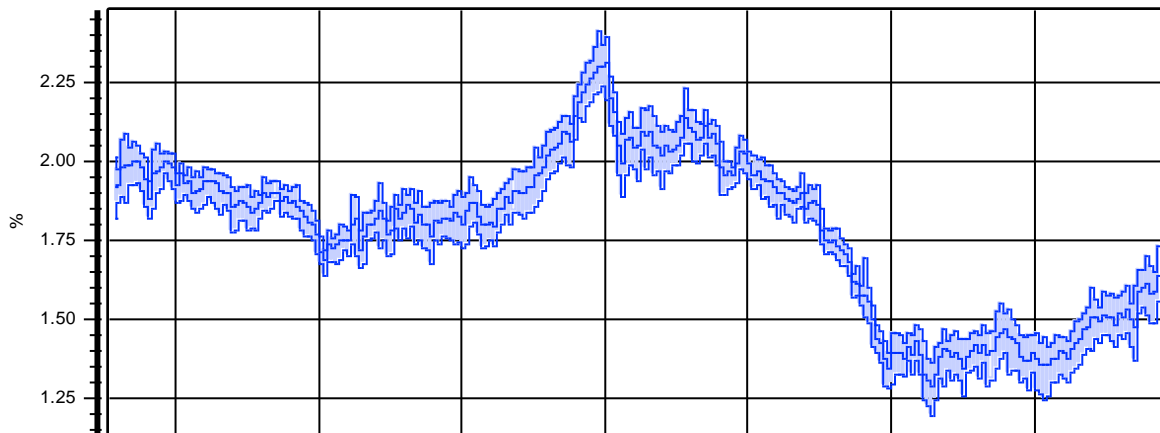
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— A VThd



— B VThd

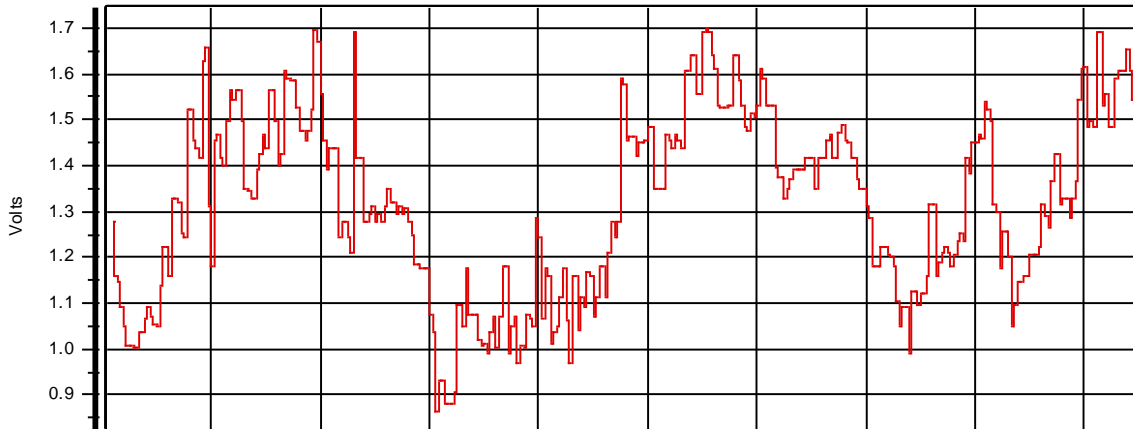


— C VThd

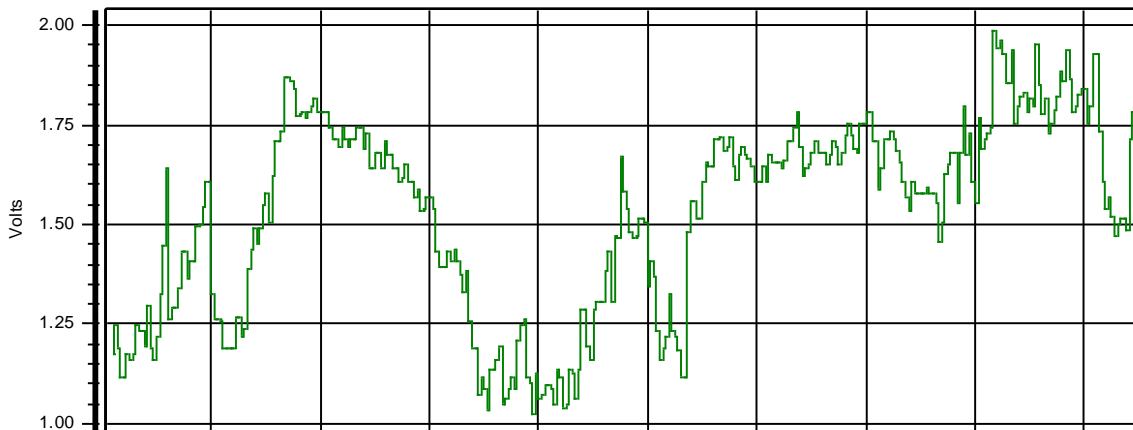
00:00 06:00 12:00 18:00 00:00 06:00 12:00
 25/03/2012 26/03/2012
 Sunday Monday

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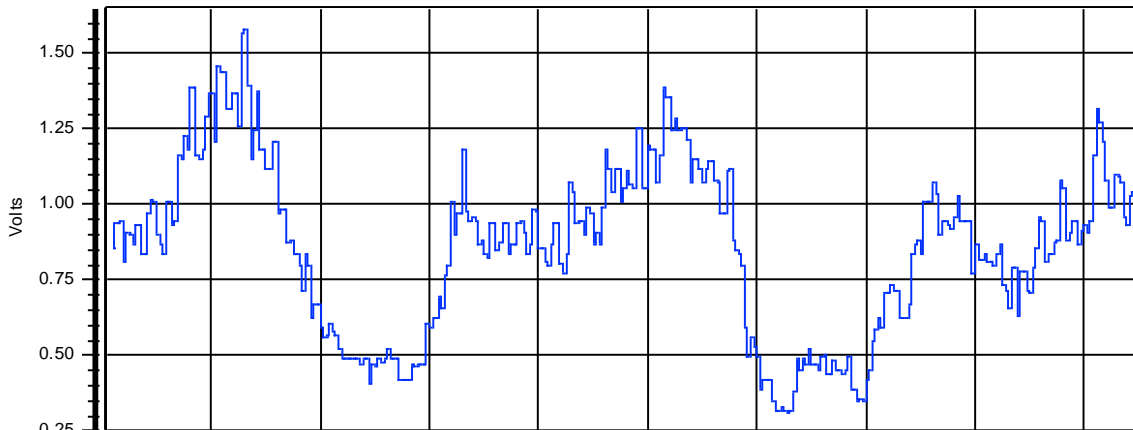
Timeplot Voltage Spectra



— A VHam(150Hz)



— B VHam(150Hz)

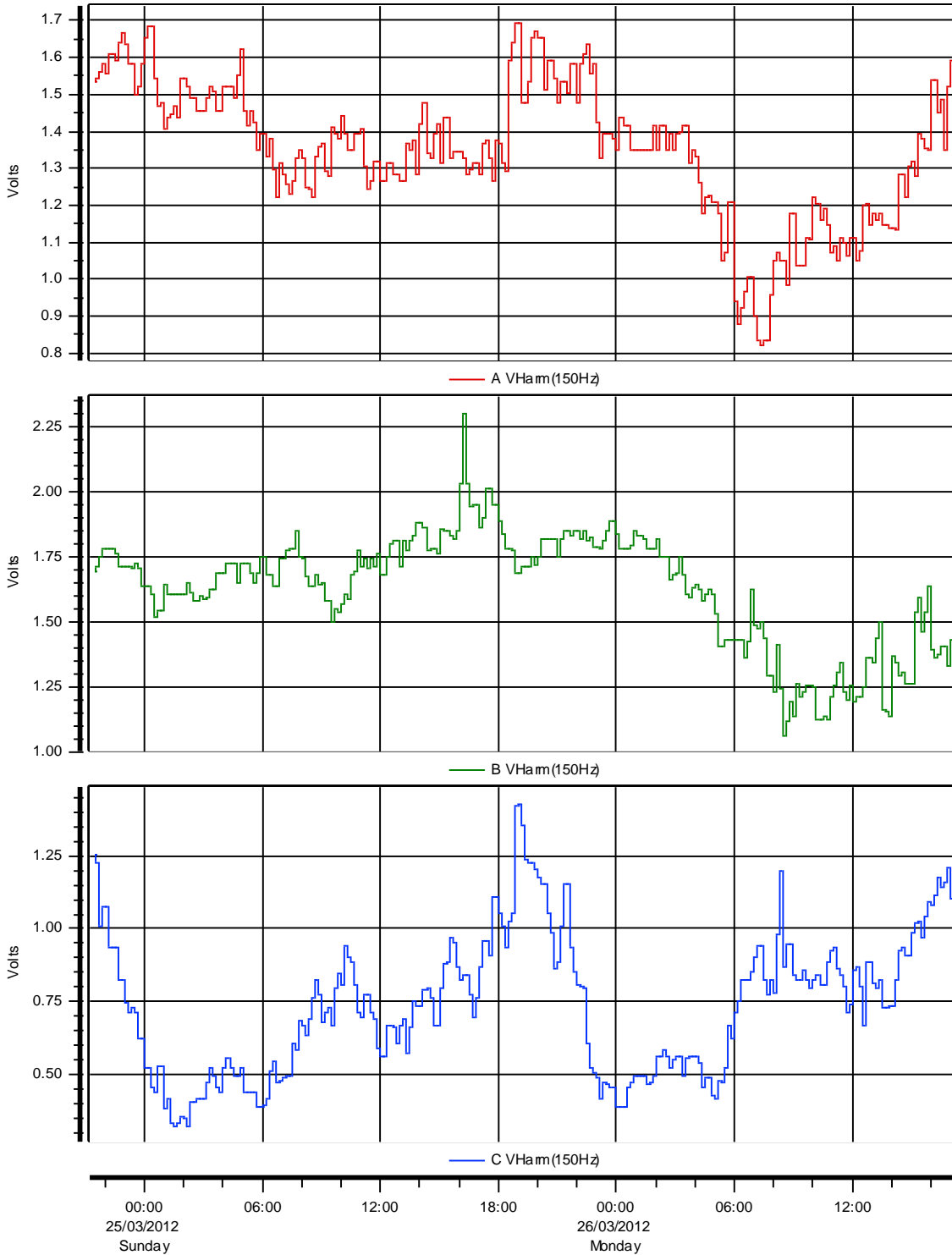


— C VHam(150Hz)

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 Thursday Friday Saturday

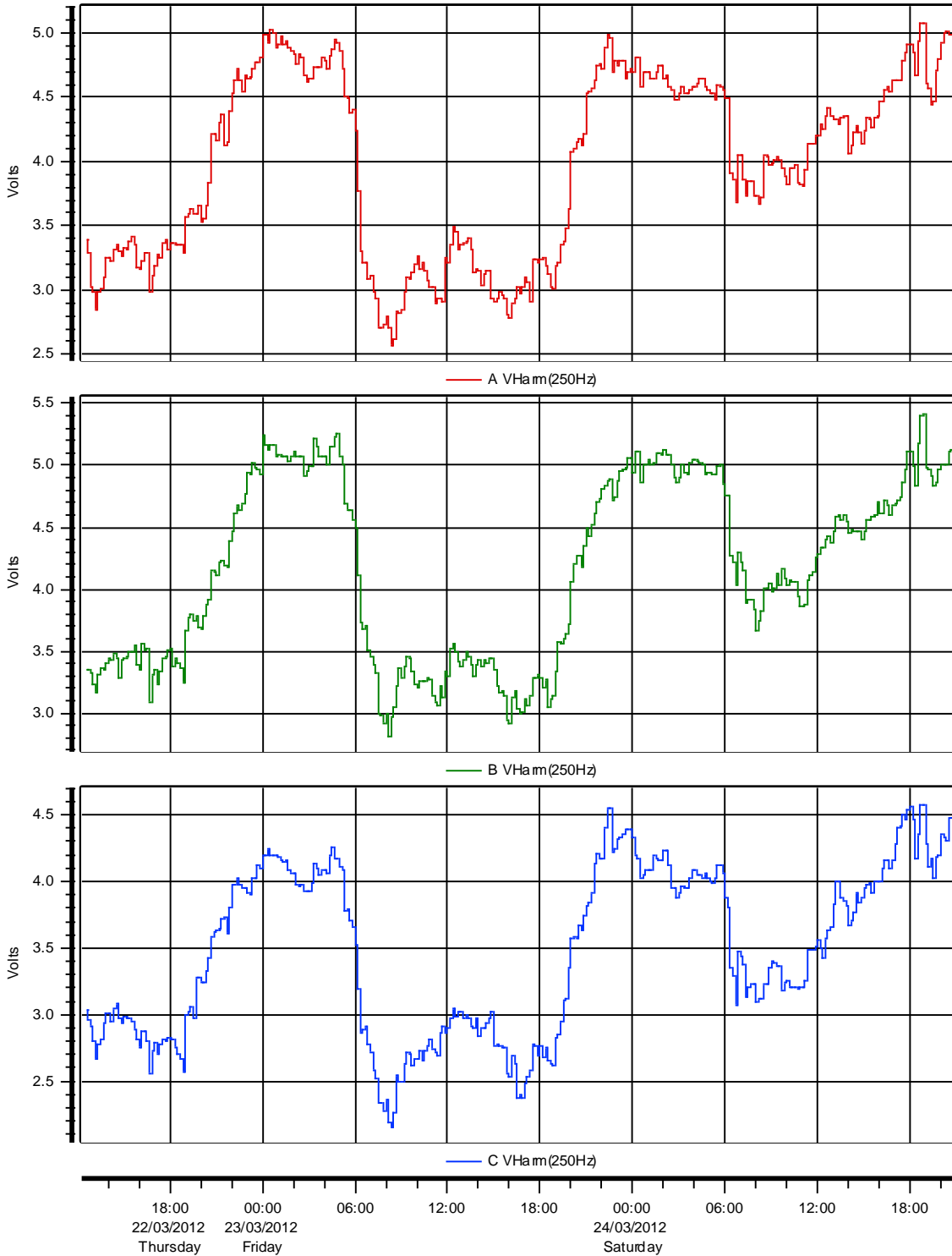
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Timeplot
Voltage Spectra



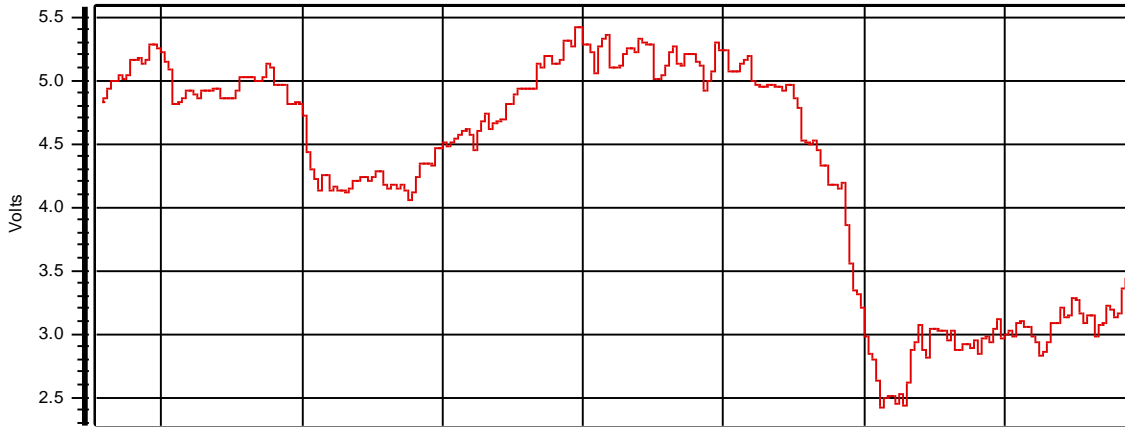
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Timeplot
Voltage Spectra

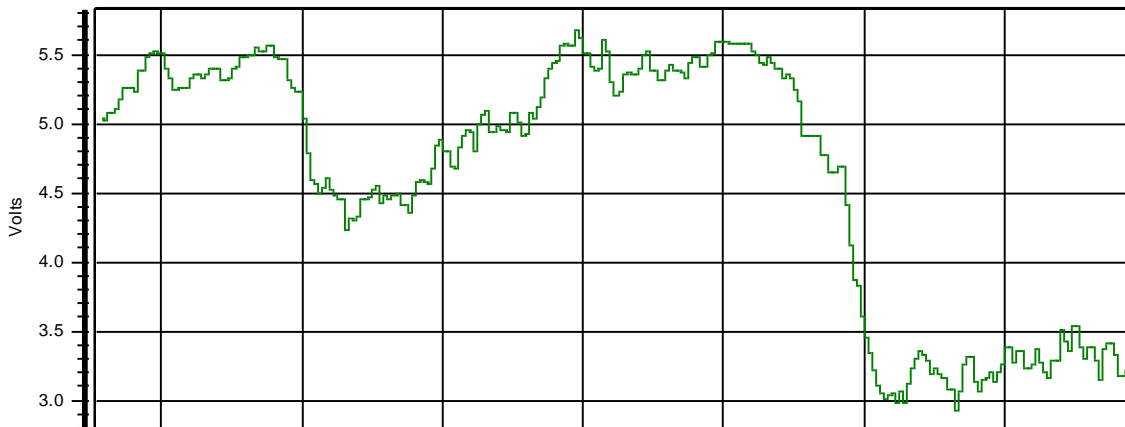


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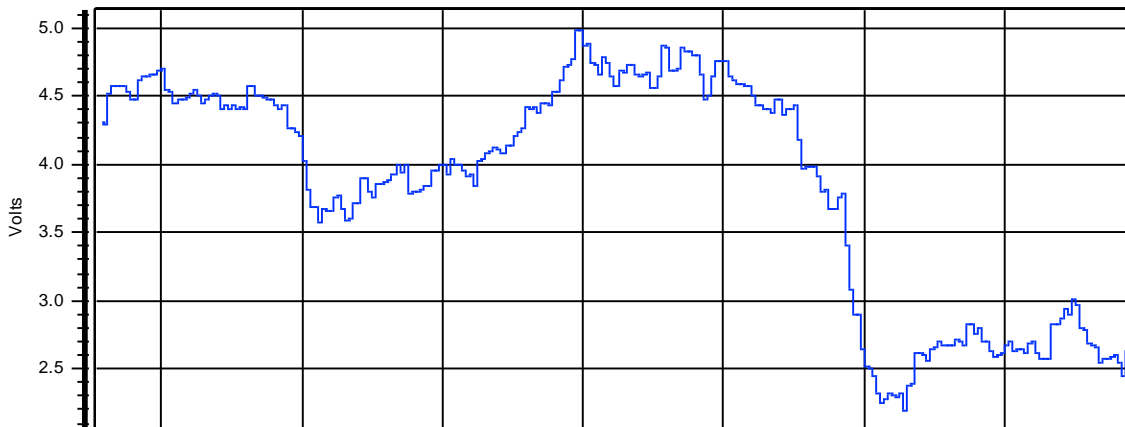
Timeplot Voltage Spectra



— A VHam(250Hz)



— B VHam(250Hz)

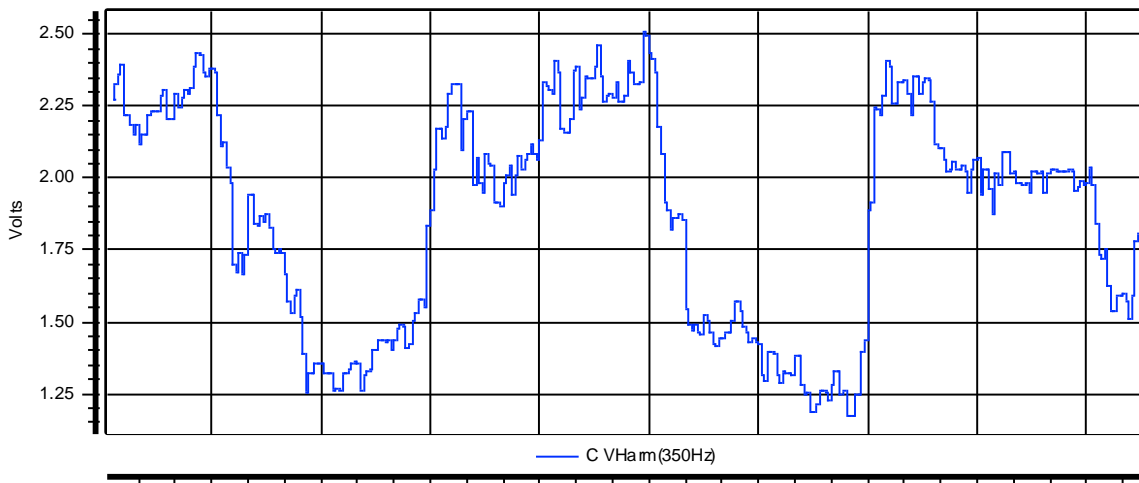
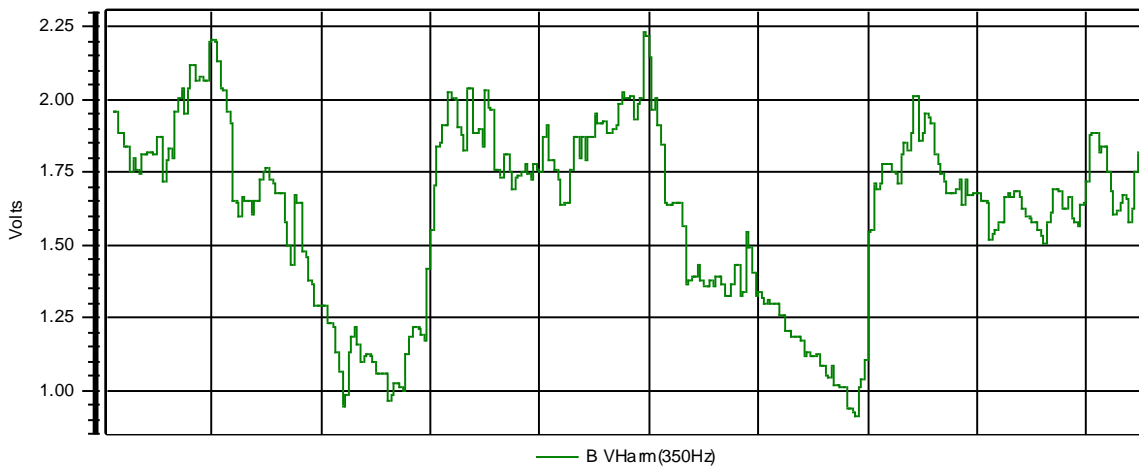
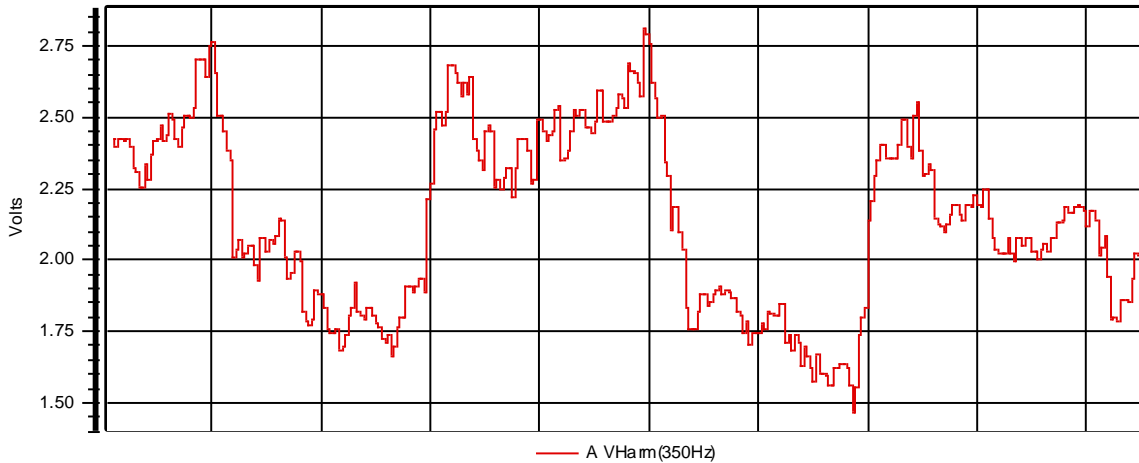


— C VHam(250Hz)

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 25/03/2012 26/03/2012
 Sunday Monday

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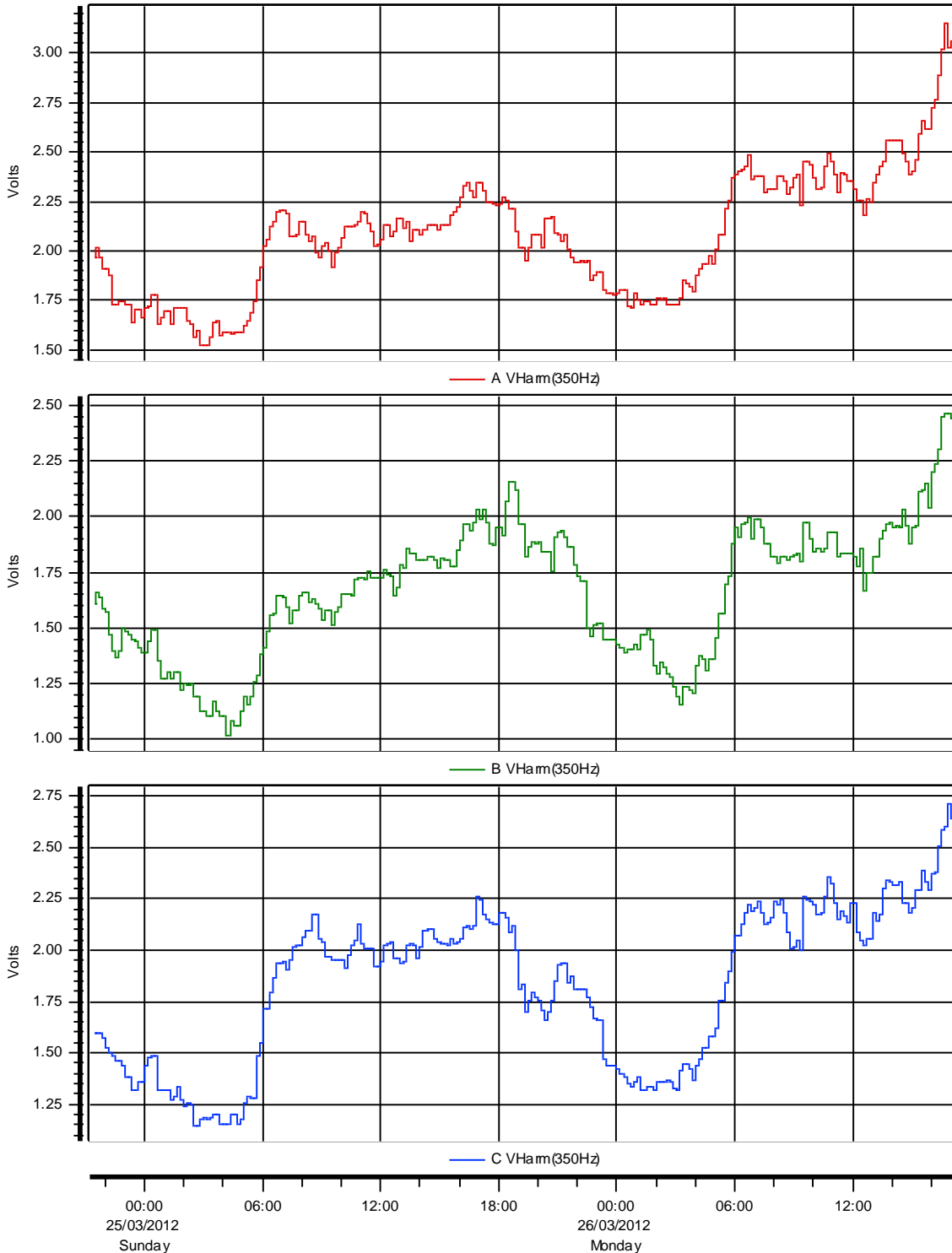
Timeplot Voltage Spectra



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 22/03/2012 23/03/2012 24/03/2012
 Thursday Friday Saturday

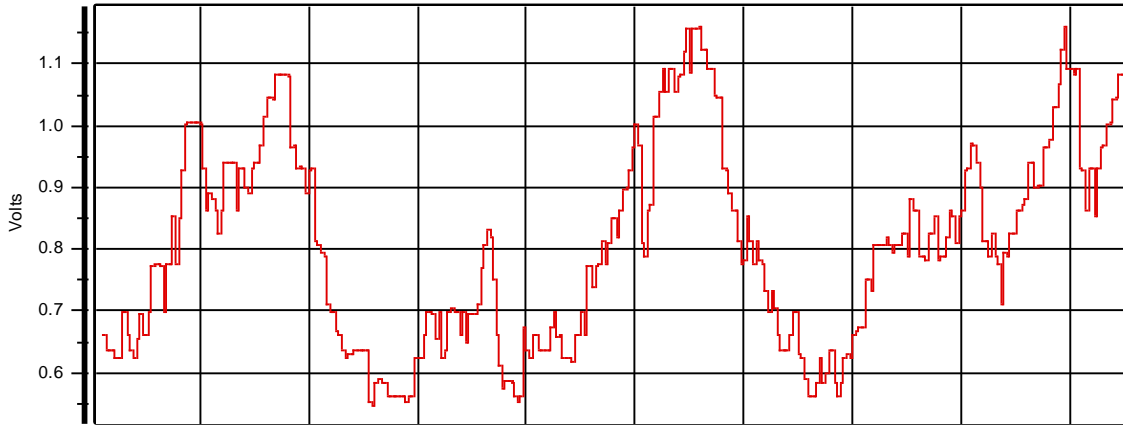
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Timeplot
Voltage Spectra

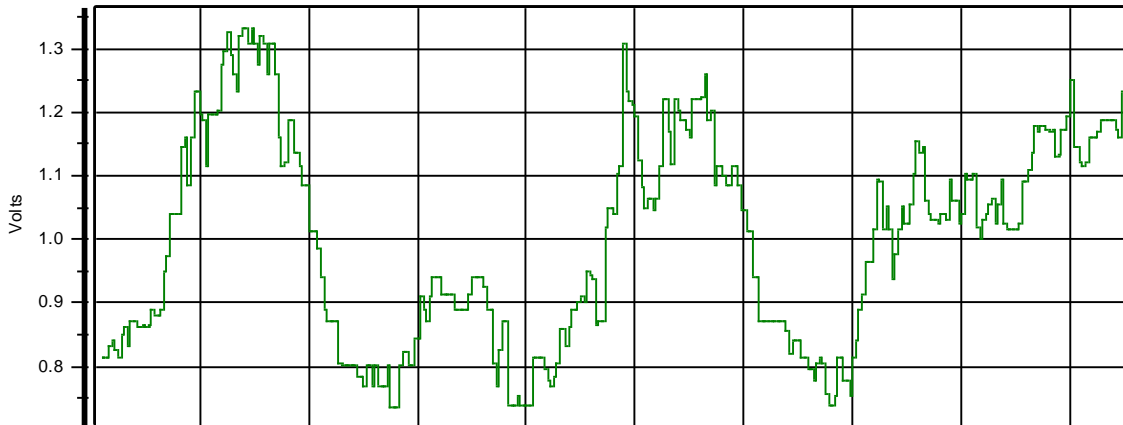


<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 28 of 39

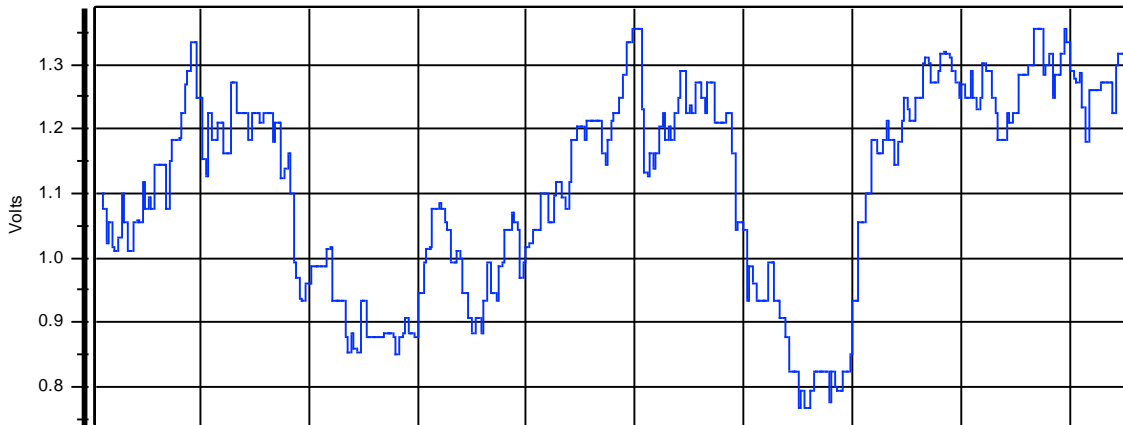
Timeplot
Voltage Spectra



— A VHam(450Hz)



— B VHam(450Hz)

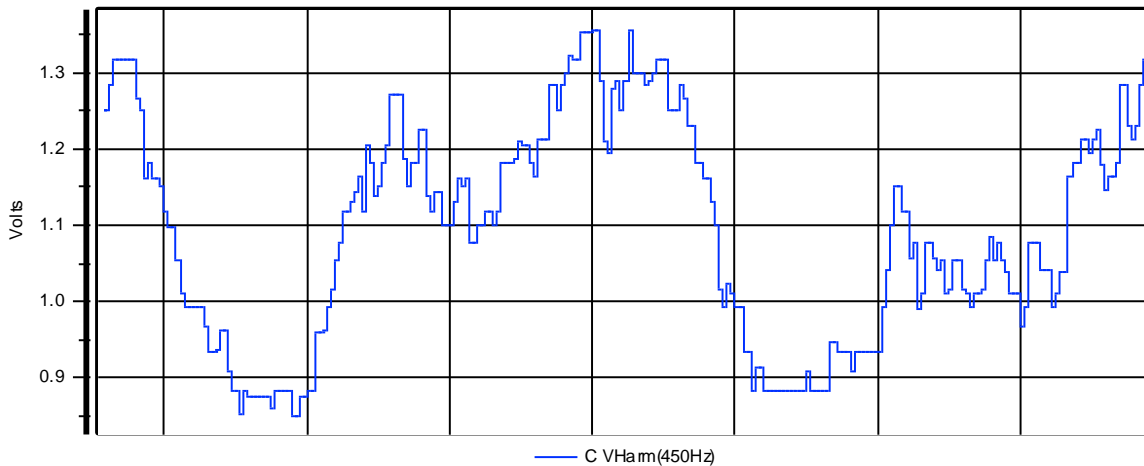
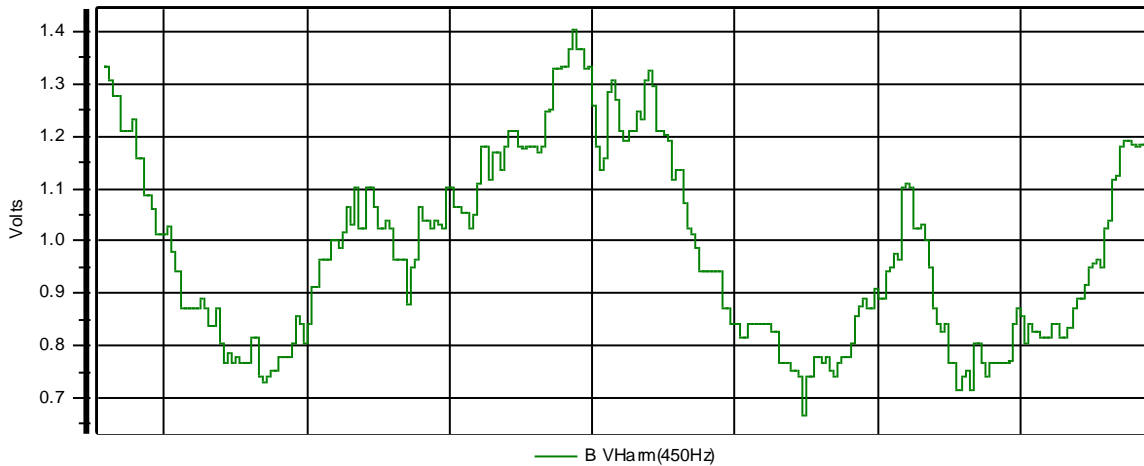
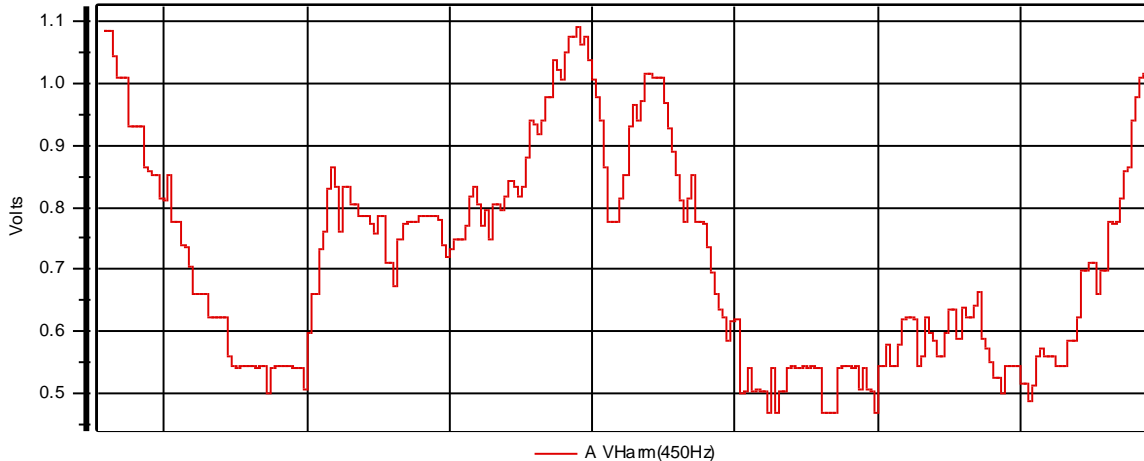


— C VHam(450Hz)

18:00 00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00
 22/03/2012 23/03/2012 24/03/2012
 Thursday Friday Saturday

<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
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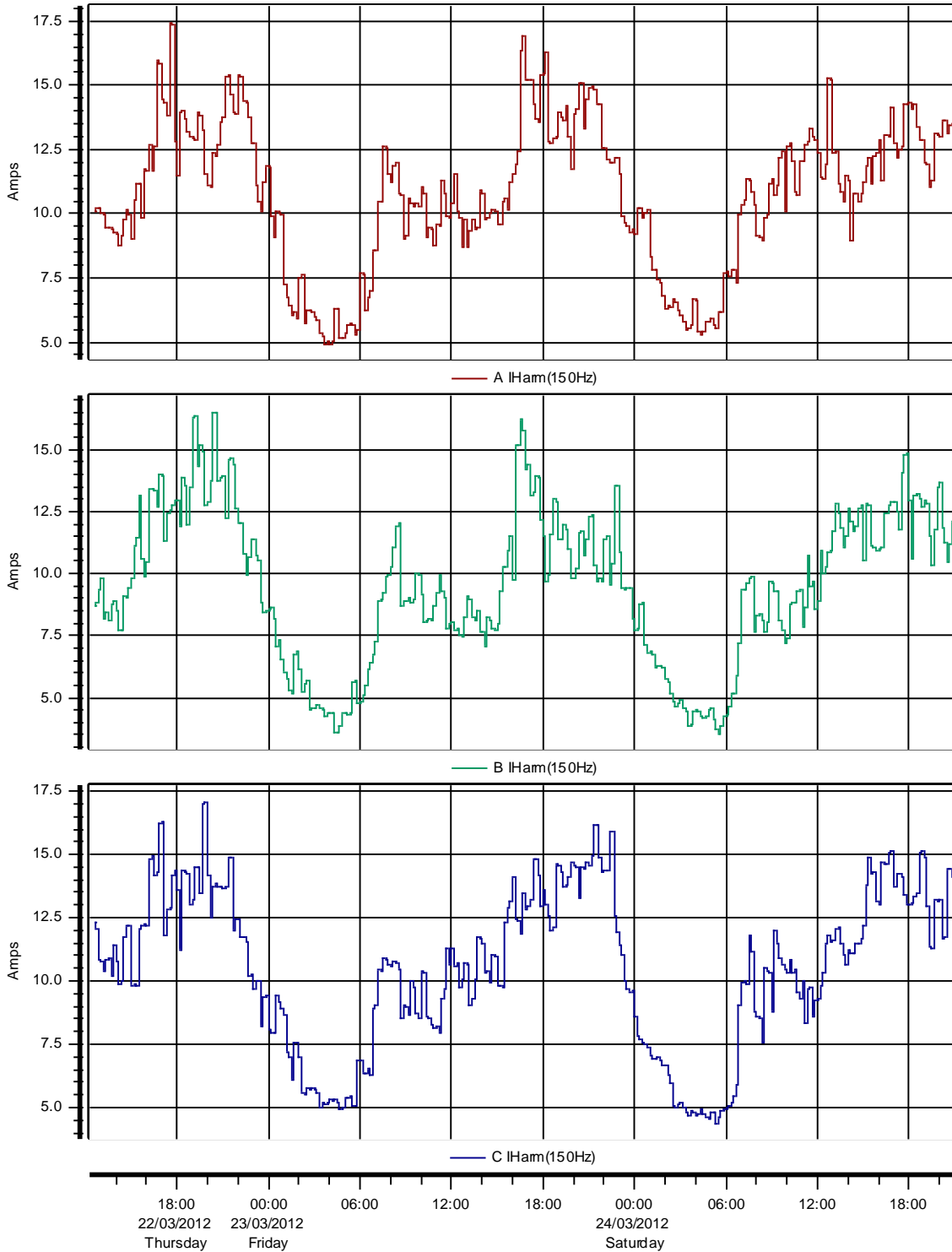
Timeplot Voltage Spectra



00:00 06:00 12:00 18:00 00:00 06:00 12:00
 25/03/2012 26/03/2012
 Sunday Monday

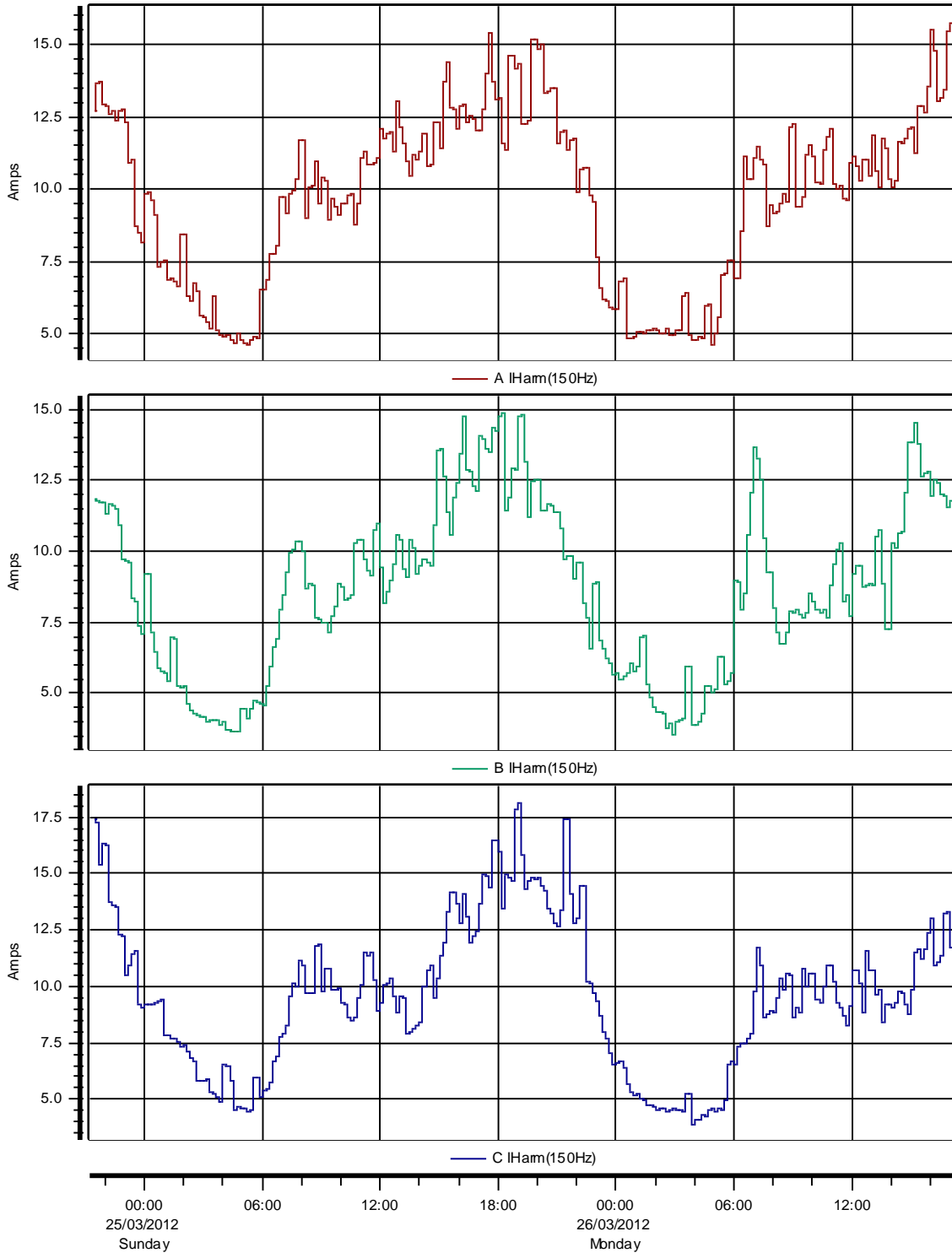
<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 30 of 39

Timeplot
Current Spectra



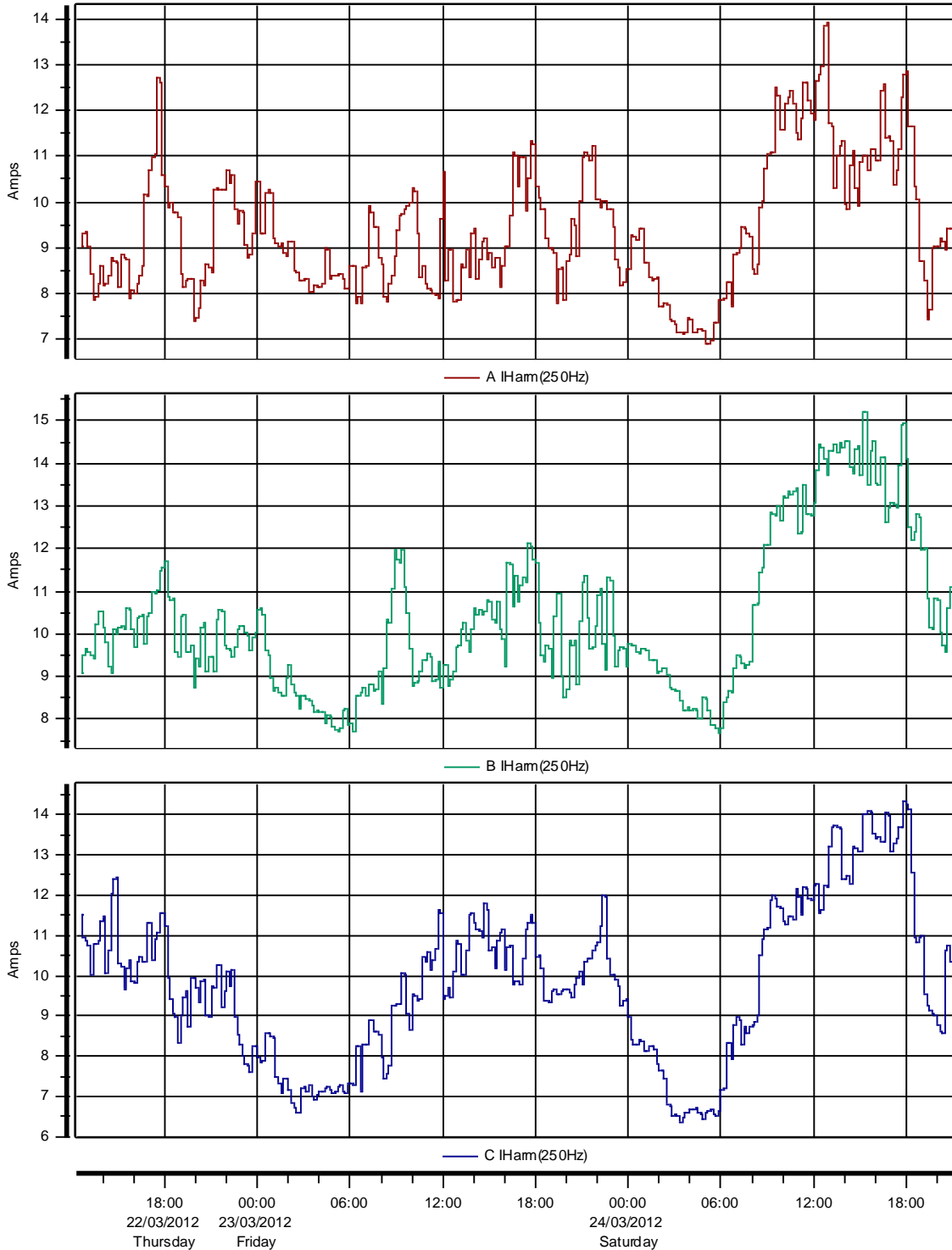
<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 31 of 39

Timeplot
Current Spectra



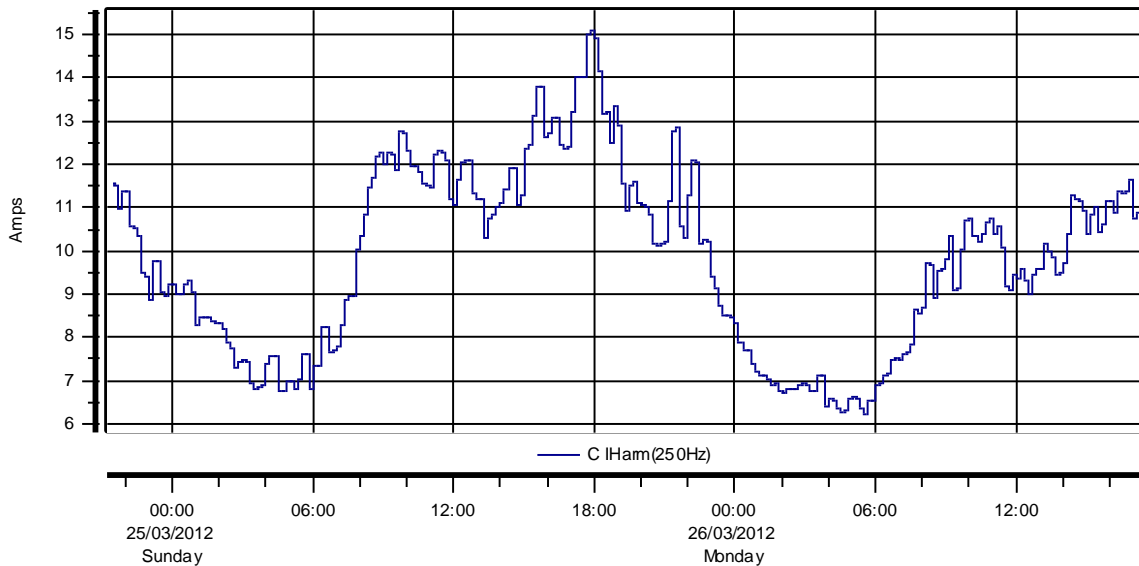
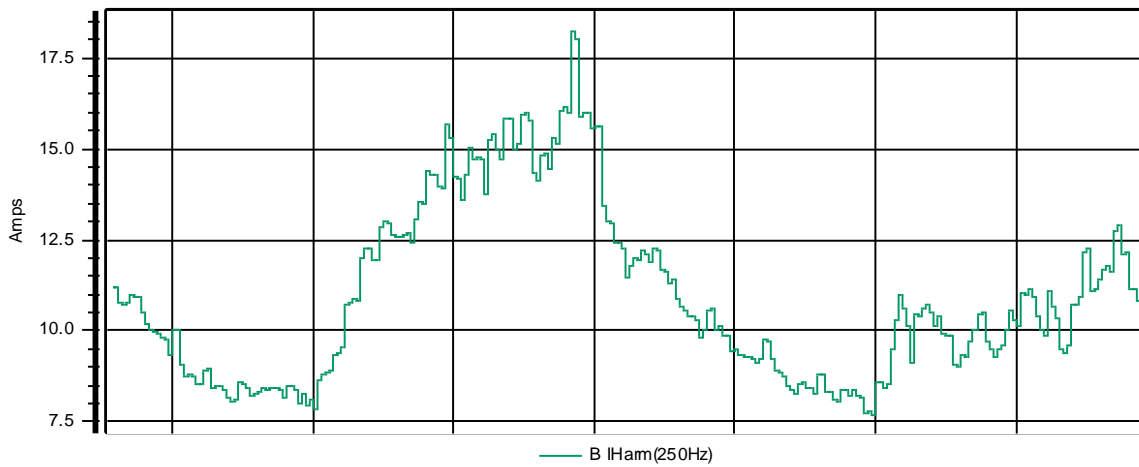
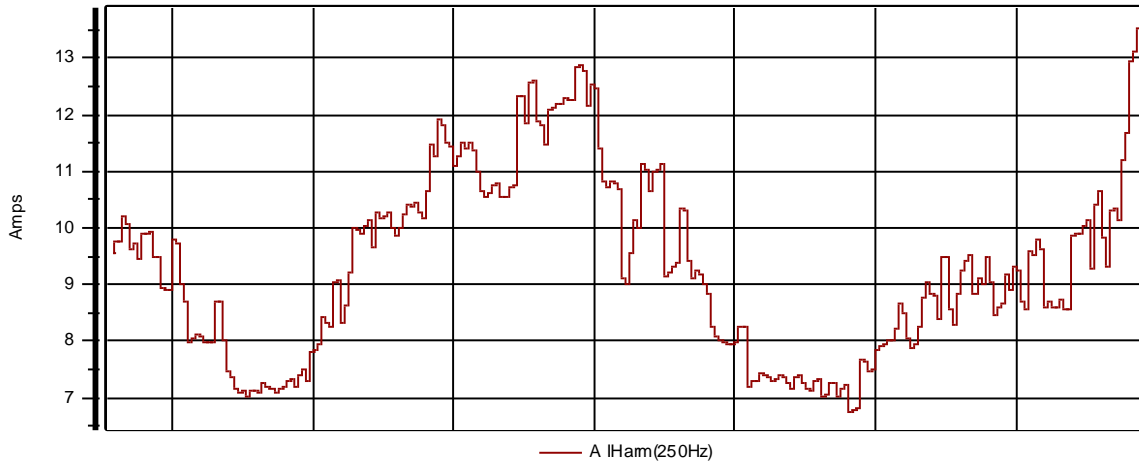
<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 32 of 39

Timeplot
Current Spectra



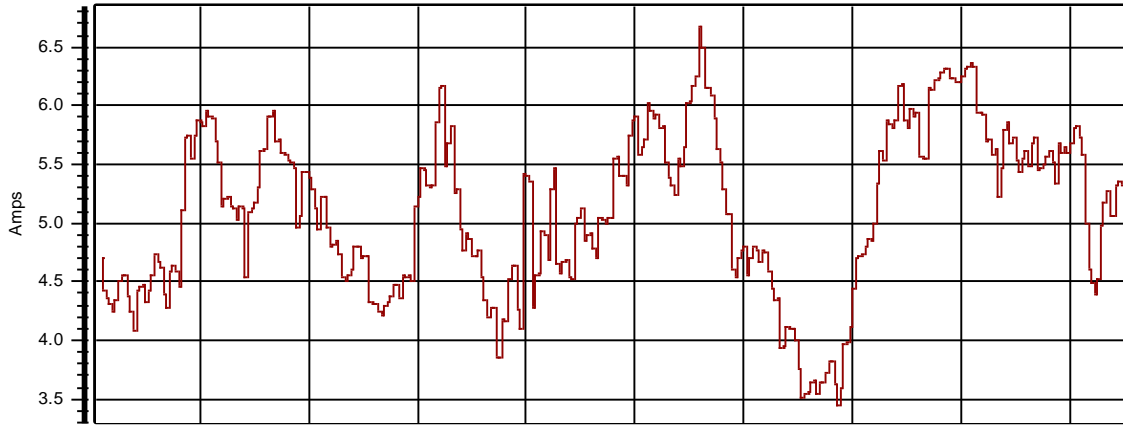
<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 33 of 39

Timeplot
Current Spectra

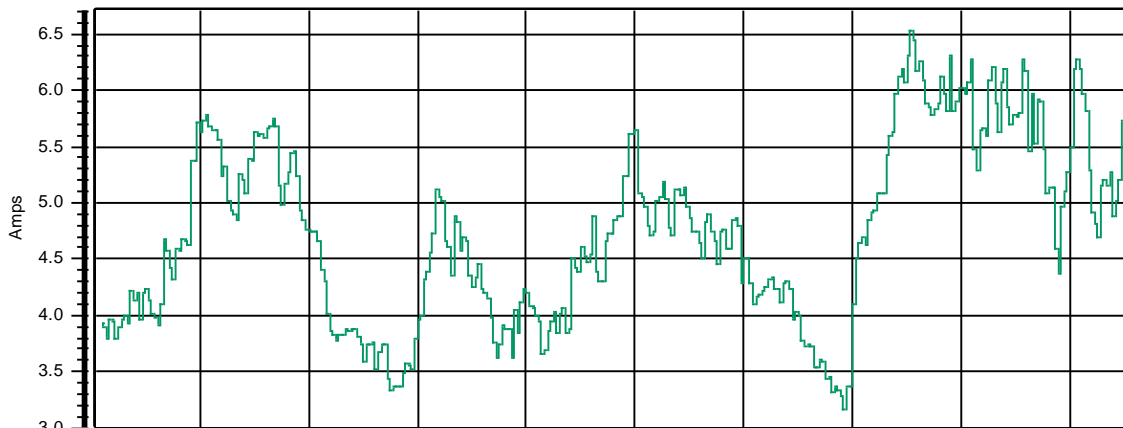


<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 34 of 39

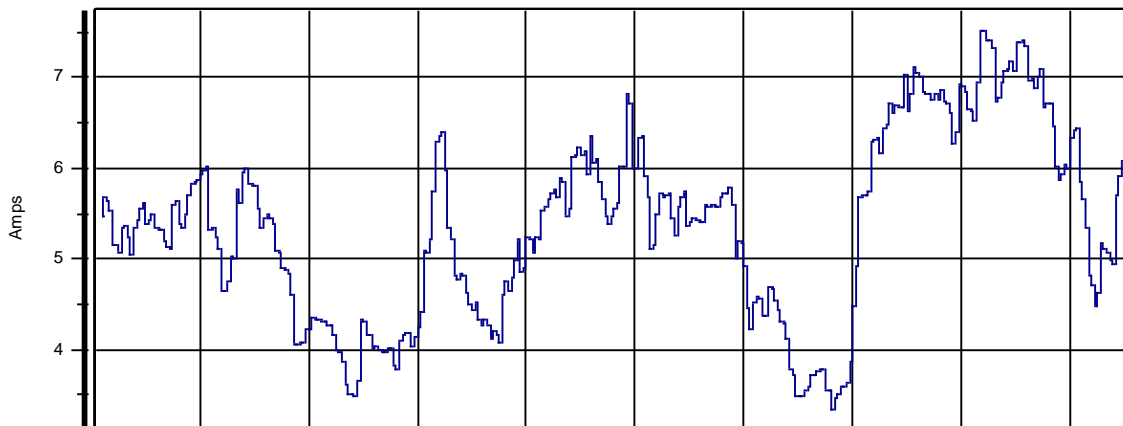
Timeplot
Current Spectra



— A IHam(350Hz)



— B IHam(350Hz)

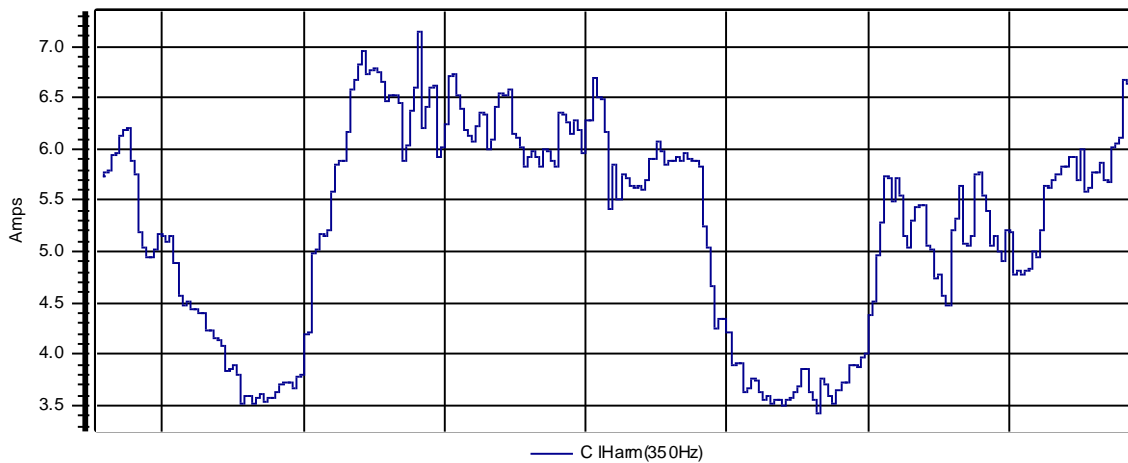
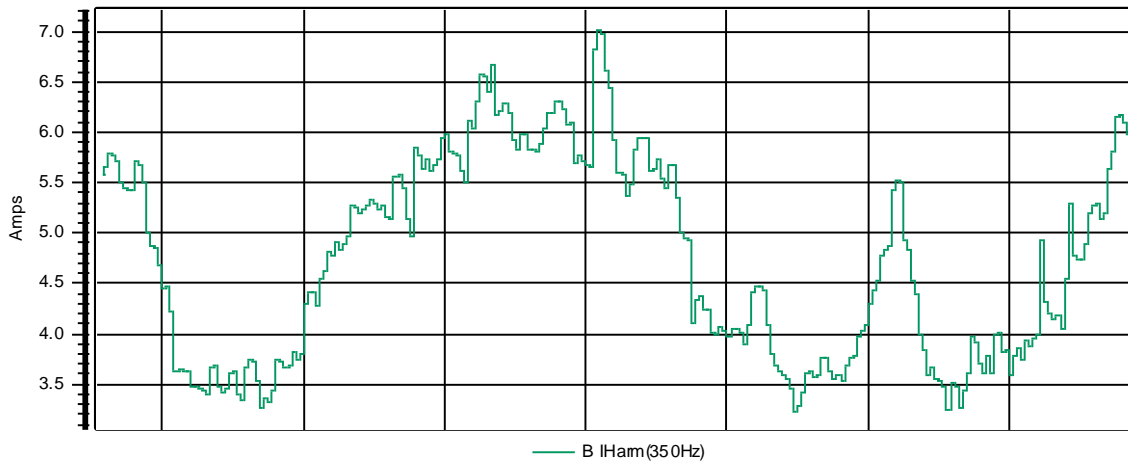
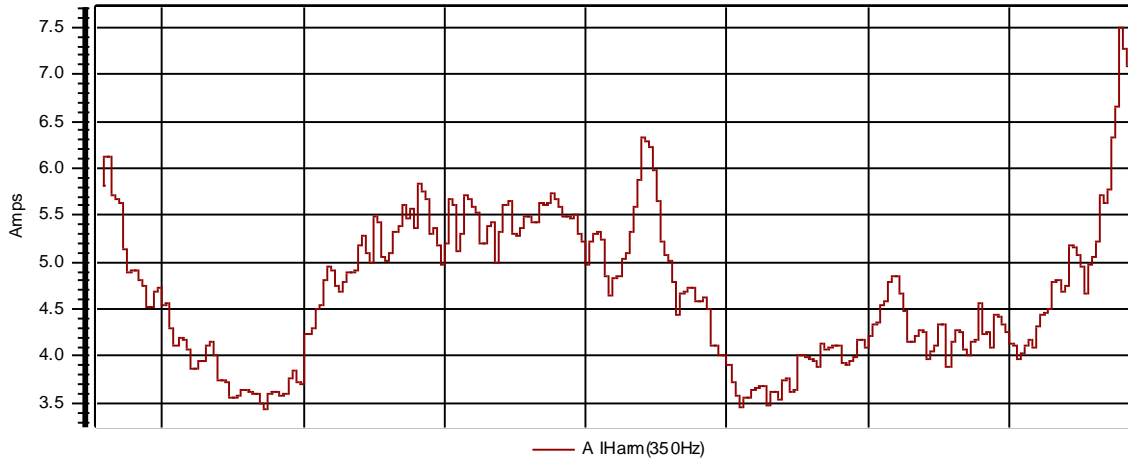


— C IHam(350Hz)

18:00 00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00
 22/03/2012 23/03/2012 24/03/2012
 Thursday Friday Saturday

<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 35 of 39

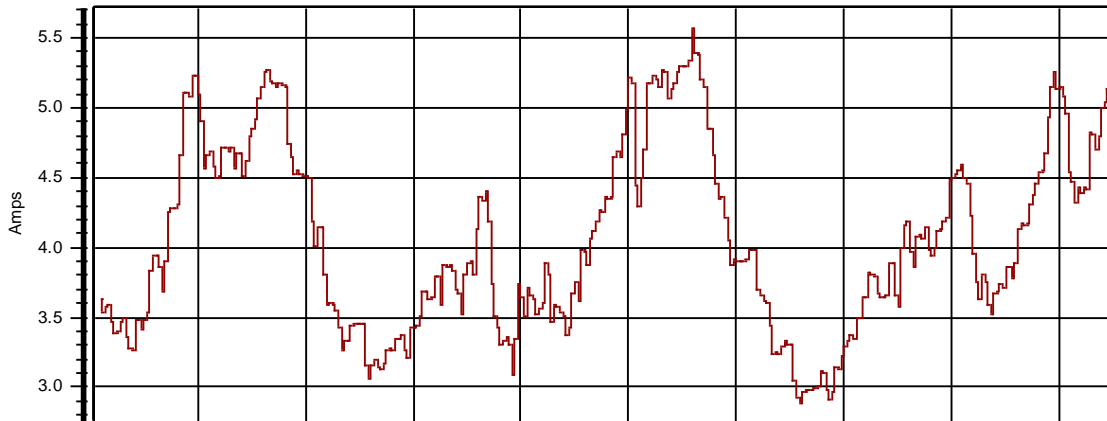
Timeplot
Current Spectra



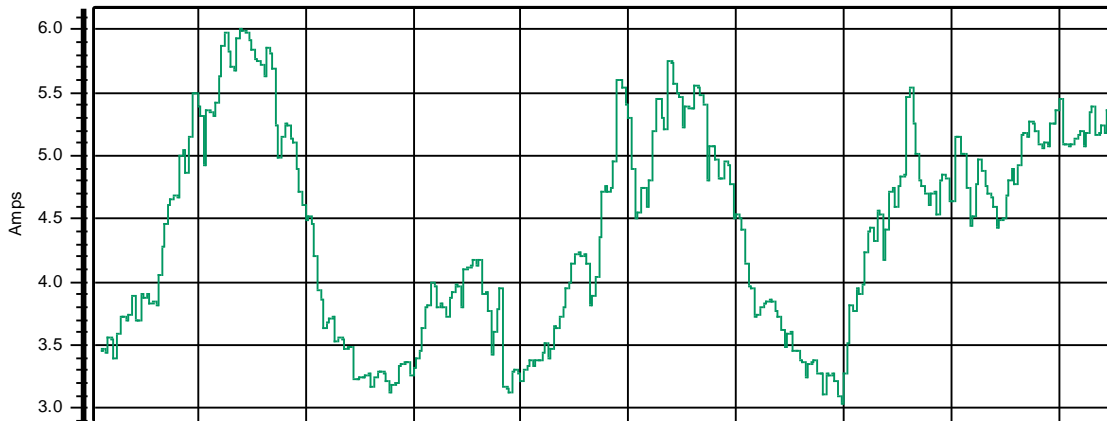
00:00 06:00 12:00 18:00 00:00 06:00 12:00
25/03/2012 26/03/2012
Sunday Monday

<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 36 of 39

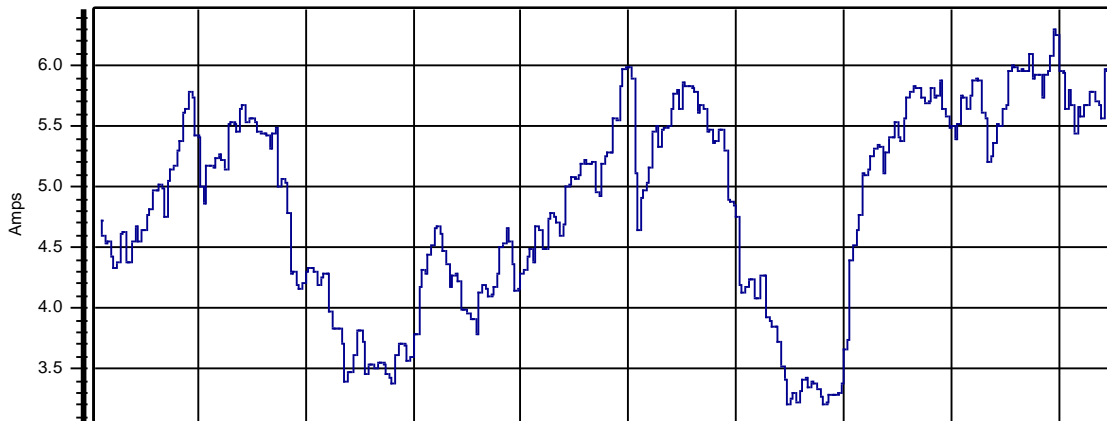
Timeplot
Current Spectra



— A IHam(450Hz)



— B IHam(450Hz)

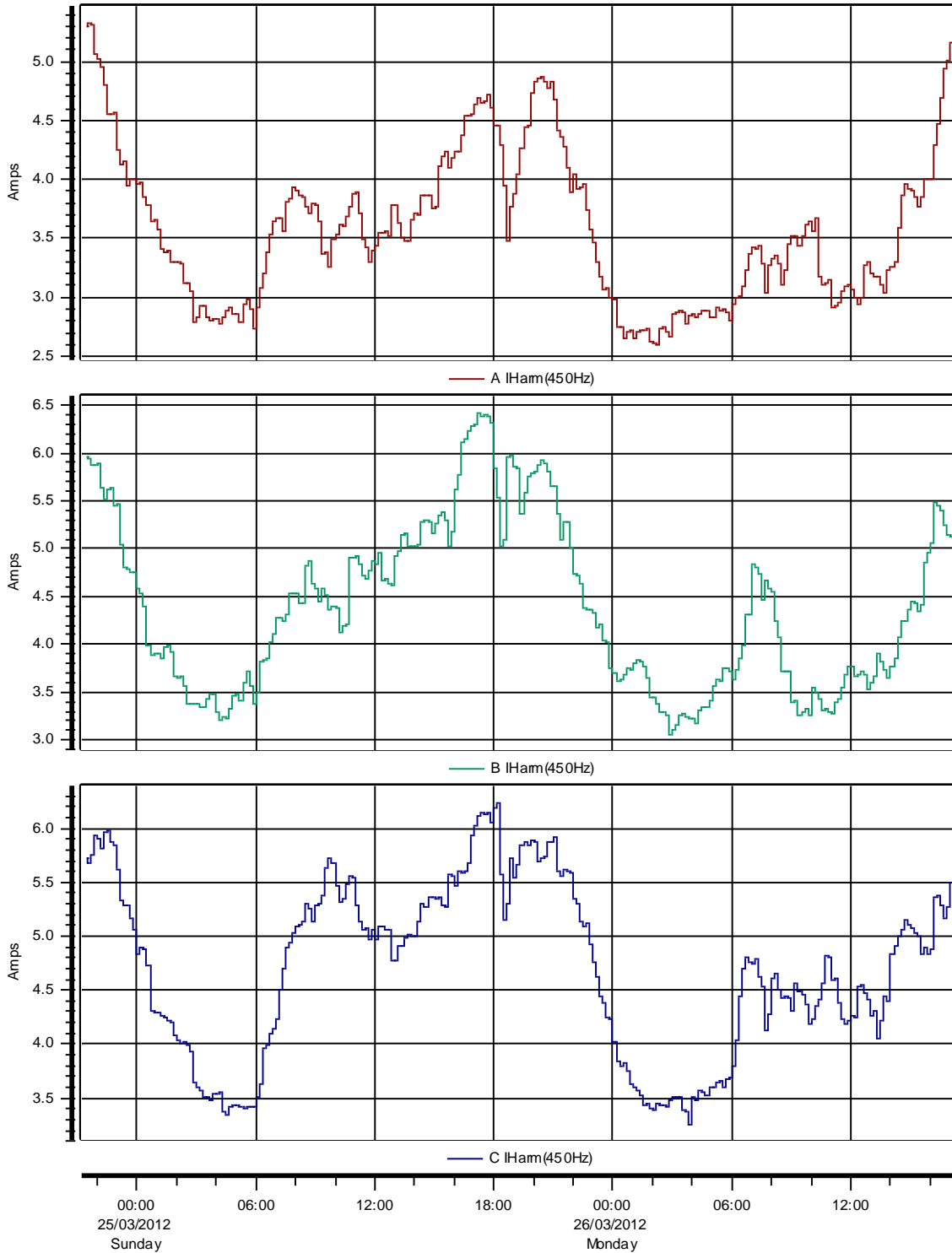


— C IHam(450Hz)

18:00 00:00 06:00 12:00 18:00 00:00 06:00 12:00 18:00
22/03/2012 23/03/2012 24/03/2012
Thursday Friday Saturday

<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 37 of 39

Timeplot
Current Spectra



<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 38 of 39

HARMONICS COMPARED AGAINST LIMITS

Site: HOWARD STREET

Measured from 22/03/2012 12:20:12.0 to 24/03/2012 21:15:34.0

G5/4 Stage 1 Curr. Harm. >16A per Phase

Measured Current Harmonics

	Limit	CHA	CHB	CHC	Status
H02	28.90 A	0.54	0.67	0.69	PASSED
H03	48.10 A	12.44	11.54	12.53	PASSED
H04	9.00 A	0.24	0.32	0.26	PASSED
H05	28.90 A	10.43	12.64	12.16	PASSED
H06	3.00 A	0.21	0.15	0.18	PASSED
H07	41.20 A	5.53	5.28	6.33	PASSED
H08	7.20 A	0.16	0.16	0.15	PASSED
H09	9.60 A	4.85	5.20	5.53	PASSED
H10	5.80 A	0.15	0.14	0.14	PASSED
H11	39.40 A	2.84	2.63	2.38	PASSED
H12	1.20 A	0.13	0.12	0.12	PASSED
H13	27.80 A	2.80	3.32	3.60	PASSED
H14	2.10 A	0.14	0.13	0.10	PASSED
H15	1.40 A	2.05	2.31	2.31	FAILED
H16	1.80 A	0.17	0.16	0.14	PASSED
H17	13.60 A	1.45	1.77	1.22	PASSED
H18	0.80 A	0.14	0.12	0.09	PASSED
H19	9.10 A	2.27	2.24	1.62	PASSED
H20	1.40 A	0.11	0.07	0.06	PASSED
H21	0.70 A	1.06	0.88	0.88	FAILED
H22	1.30 A	0.11	0.08	0.06	PASSED
H23	7.50 A	0.96	0.87	0.56	PASSED
H24	0.60 A	0.07	0.05	0.03	PASSED
H25	4.00 A	0.93	0.69	0.57	PASSED
H26	1.10 A	0.06	0.04	0.03	PASSED
H27	0.50 A	0.46	0.44	0.25	PASSED
H28	1.00 A	0.05	0.04	0.03	PASSED
H29	3.10 A	0.60	0.55	0.41	PASSED
H30	0.50 A	0.03	0.02	0.01	PASSED
H31	2.80 A	0.44	0.38	0.28	PASSED
H32	0.90 A	0.03	0.02	0.01	PASSED
H33	0.40 A	0.31	0.30	0.18	PASSED
H34	0.80 A	0.02	0.02	0.01	PASSED
H35	2.30 A	0.30	0.24	0.17	PASSED
H36	0.40 A	0.01	0.01	0.01	PASSED
H37	2.10 A	0.23	0.22	0.14	PASSED
H38	0.80 A	0.02	0.01	0.01	PASSED
H39	0.40 A	0.18	0.17	0.10	PASSED
H40	0.70 A	0.01	0.01	0.01	PASSED
H41	1.80 A	0.17	0.15	0.10	PASSED
H42	0.30 A	0.01	0.01	0.00	PASSED
H43	1.60 A	0.16	0.15	0.09	PASSED
H44	0.70 A	0.01	0.01	0.00	PASSED
H45	0.30 A	0.09	0.08	0.05	PASSED
H46	0.60 A	0.01	0.01	0.00	PASSED
H47	1.40 A	0.06	0.05	0.04	PASSED
H48	0.30 A	0.00	0.00	0.00	PASSED
H49	1.30 A	0.05	0.05	0.03	PASSED
H50	0.60 A	0.00	0.00	0.00	PASSED

<i>Customer</i> ENW		<i>ABB Ref.</i>	
<i>Project</i> Howard Street Harmonic Survey		<i>Cust. Ref.</i>	
<i>Dealt with by</i> SCJ	<i>Date</i> 27/03/2014	<i>Issue</i> 0	<i>Page</i> 39 of 39

HARMONICS COMPARED AGAINST LIMITS

Site: HOWARD STREET

Measured from 24/03/2012 21:16:02.0 to 26/03/2012 17:28:54.0

G5/4 Stage 1 Curr. Harm. >16A per Phase

Measured Current Harmonics

	Limit	CHA	CHB	CHC	Status
H02	28.90 A	0.53	0.53	0.64	PASSED
H03	48.10 A	11.78	10.54	12.54	PASSED
H04	9.00 A	0.27	0.29	0.24	PASSED
H05	28.90 A	11.19	13.96	11.74	PASSED
H06	3.00 A	0.20	0.14	0.16	PASSED
H07	41.20 A	5.31	5.64	5.98	PASSED
H08	7.20 A	0.16	0.16	0.16	PASSED
H09	9.60 A	4.44	5.52	5.60	PASSED
H10	5.80 A	0.15	0.14	0.14	PASSED
H11	39.40 A	2.37	1.87	2.29	PASSED
H12	1.20 A	0.13	0.12	0.12	PASSED
H13	27.80 A	2.52	3.03	3.44	PASSED
H14	2.10 A	0.14	0.13	0.11	PASSED
H15	1.40 A	1.99	2.50	2.15	FAILED
H16	1.80 A	0.16	0.14	0.13	PASSED
H17	13.60 A	1.38	1.46	1.11	PASSED
H18	0.80 A	0.12	0.11	0.08	PASSED
H19	9.10 A	2.12	2.43	1.59	PASSED
H20	1.40 A	0.10	0.08	0.06	PASSED
H21	0.70 A	1.02	1.05	1.00	FAILED
H22	1.30 A	0.10	0.09	0.06	PASSED
H23	7.50 A	0.83	0.85	0.55	PASSED
H24	0.60 A	0.07	0.06	0.03	PASSED
H25	4.00 A	1.06	0.87	0.58	PASSED
H26	1.10 A	0.06	0.04	0.03	PASSED
H27	0.50 A	0.46	0.41	0.26	PASSED
H28	1.00 A	0.05	0.04	0.03	PASSED
H29	3.10 A	0.60	0.56	0.40	PASSED
H30	0.50 A	0.03	0.03	0.01	PASSED
H31	2.80 A	0.49	0.43	0.29	PASSED
H32	0.90 A	0.03	0.02	0.01	PASSED
H33	0.40 A	0.29	0.27	0.18	PASSED
H34	0.80 A	0.03	0.02	0.01	PASSED
H35	2.30 A	0.30	0.26	0.16	PASSED
H36	0.40 A	0.02	0.01	0.01	PASSED
H37	2.10 A	0.23	0.20	0.12	PASSED
H38	0.80 A	0.02	0.01	0.01	PASSED
H39	0.40 A	0.16	0.17	0.10	PASSED
H40	0.70 A	0.01	0.01	0.01	PASSED
H41	1.80 A	0.17	0.15	0.10	PASSED
H42	0.30 A	0.01	0.01	0.00	PASSED
H43	1.60 A	0.14	0.13	0.09	PASSED
H44	0.70 A	0.01	0.01	0.00	PASSED
H45	0.30 A	0.09	0.08	0.05	PASSED
H46	0.60 A	0.01	0.01	0.00	PASSED
H47	1.40 A	0.05	0.04	0.03	PASSED
H48	0.30 A	0.01	0.00	0.00	PASSED
H49	1.30 A	0.05	0.04	0.03	PASSED
H50	0.60 A	0.00	0.00	0.00	PASSED