NATIONAL PHYSICAL LABORATORY
Teddington Middlesex UK TW11 0LW Switchboard 020 8977 3222

Certificate of Calibration

UKAS CALIBRATION
0478

Universal Power Analyser
Type PM6000 S/No. 100006700004

FOR	Voltech Instruments Limited 148 Harwell Science and Innovation Campus Didcot OX11 0RA
ORDER REFERENCE	28697 dated 20 April 2007
MANUFACTURER	Voltech Instruments Limited
DATE OF CALIBRATION	3 May 2007 to 11 May 2007
MEASUREMENT NUMBER	ED.17/07/007/EtD 335.079

The mains circuit of the Power Analyser was energised from a nominal 230 V mains supply for at least 24 hours before any tests were carried out.

The instrument was tested at a mean ambient temperature of 23.0 ± 1.0 °C with the exception of the interharmonic measurements where the mean ambient temperature was 21.0 ± 2.0 °C.

The reported uncertainties are based on a standard uncertainty multiplied by a coverage factor as specified, providing a level of confidence of approximately 95%. The uncertainties relate only to the measured value and carry no implication regarding the stability of the instrument. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

The Power Analyser was used with a 2.4 GHz Pentium 4 PC with 512 MB of RAM. Drive C contained a 19.5 GB hard disk drive, with approximately 9.7 GB free. The computer was interfaced to the Power Analyser using the customer provided RS232 interface lead. Customer provided software was used which was identified as follows:

IEC61000-3 For PM6000 Release 1.04.02, IEC1000.exe, Last Modified 23/04/07, 942,080 bytes.

Reference: E07040133/1

Date of Issue: 17 May 2007

Checked by: BT

Signed: P S Wright

Name: P S Wright

(Authorised Signatory)

for Managing Director

For all tests the following configuration was selected via the Config / View Settings menu:

WIRING:	1 Phase 2 Wire
RANGE:	Voltage 500V; Current 25A
COUPLING:	AC+DC
SCALING:	Ch 1: Volts 1, Current 1
FILTER:	2 MHz
FREQUENCY SOURCE:	Volts
PHASE REFERENCE:	Volts
MODE:	IEC Harmonics
INTEGRATE:	Off

Under View Hardware, the following was recorded.

PM6000:	S/N 100006700004; Firmware v1.13.05 RC1
Channel 1:	S/N 090015500069, Hardware 21, Date Calibrated 4 Jul 2006
Shunt Type 30A:	S/N 091024300051, Hardware 4, Date Calibrated 11 Aug 2006
Channel 2:	S/N 090015500007, Hardware 21, Date Calibrated 5 Jul 2006
Shunt Type 30A:	S/N 091024300051, Hardware 4, Date Calibrated 11 Aug 2006
Channel 3:	S/N 090015500035, Hardware 21, Date Calibrated 6 Jul 2006
Shunt Type 1A:	S/N 091024300031, Hardware 4, Date Calibrated 18 Aug 2005

The current terminals marked 'CH1' were used in all tests. The voltage terminals marked 'CH1' were used in all tests. The current and voltage terminals marked 'LO' were independently connected to earth potential.

EN 61000-4-7: 2002, Section 5.3 states that "the uncertainty terms are related to the permissible limits (5 % of the permissible limits) or the rated current (I_r) of the tested appliance (0.15 % I_r) whichever is greater". Where applicable Target Errors based on 5 % of reading have been given in the following tables.

Steady State Harmonics Tests

Purpose of Tests

These tests assess the ability of the Power Analyser to correctly measure steady state harmonics to an accuracy within the 5 % limit stated in EN 61000-4-7: 2002, Section 5.3, when testing equipment having Class A or Class D characteristics.

Measurement Method

Harmonics tests were carried out using the program supplied as described on Page 1. The program was configured to 'EN61000:2001', 'Fluctuating Harmonics' mode, with a test time of 2 minutes and 30 seconds. The Power Analyser results were written to a data file on the controlling computer and the reported results were obtained by averaging the results given in the data file.

The Power Analyser was tested with a 50 Hz fundamental current and appropriate levels of associated harmonic currents. The fundamental component of the applied current was phase-locked to the signal that supplied the voltage channel.

Class-A Wave Shape

The nominal amplitude of the harmonics was set at the Class-A limits as defined in Table 1 of IEC61000-3-2: 2000-08, page 33. The fundamental amplitude was set to a nominal 2.3 A RMS. The dc component of the applied current was negligible. Voltage CH1 of the Power Analyser was supplied with a nominal 230 V RMS sinusoidal voltage at 50 Hz. The distortion of the voltage waveform was less than 0.1 % of value.

The Power Analyser program was configured to Class-A mode. The Power Analyser was configured to perform the measurements on the 25 A Peak range.

The phases of the harmonics were set such that harmonics 2, 5, 6... 37, 38 were set to zero phase relative to the fundamental and harmonics 3, 4, 7, 8...39, 40 set to 180 degrees relative to the fundamental. This combination of harmonic amplitudes and phases gives a wave shape with well defined positive and negative going peaks.

Class A Steady State Harmonics Results

The resulting harmonic amplitudes as measured by the Power Analyser are given in Table 1. The uncertainties given in Table 1 are based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95 %.

Table 1, Class A Tests					
Harmonic Number	Nominal Harmonic Amplitude (A)	Instrument Reading (A)	Instrument Error (mA)	Uncertainty in Instrument Error (mA)	Target Error (mA)
2	1.080 0	1.077 6	–2.4	±1.3	±54.0
3	2.300 0	2.298 1	–1.9	±2.6	±115.0
4	0.430 0	0.430 3	+0.3	±0.5	±21.5
5	1.140 0	1.140 4	+0.4	±1.3	±57.0
6	0.300 0	0.301 3	+1.3	±0.4	±15.0
7	0.770 0	0.769 3	–0.7	±0.9	±38.5
8	0.230 0	0.230 1	+0.1	±0.3	±11.5
9	0.400 0	0.401 4	+1.4	±0.5	±20.0
10	0.184 0	0.184 5	+0.5	±0.2	±9.2
11	0.330 0	0.329 9	–0.1	±0.4	±16.5
12	0.153 3	0.153 7	+0.3	±0.2	±7.7
13	0.210 0	0.210 6	+0.6	±0.3	±10.5
14	0.131 4	0.131 6	+0.1	±0.2	±6.6
15	0.150 0	0.150 1	+0.1	±0.2	±7.5
16	0.115 0	0.115 3	+0.3	±0.2	±5.8
17	0.132 4	0.132 1	–0.3	±0.2	±6.6
18	0.102 2	0.102 3	+0.1	±0.2	±5.1
19	0.118 4	0.118 2	–0.2	±0.2	±5.9
20	0.092 0	0.092 4	+0.4	±0.1	±4.6
21	0.107 1	0.107 7	+0.5	±0.2	±5.4
22	0.083 6	0.083 9	+0.2	±0.1	±4.2
23	0.097 8	0.097 9	+0.1	±0.2	±4.9
24	0.076 7	0.076 5	–0.2	±0.1	±3.8
25	0.090 0	0.090 7	+0.7	±0.1	±4.5
26	0.070 8	0.070 9	+0.1	±0.1	±3.5
27	0.083 3	0.083 4	+0.1	±0.1	±4.2
28	0.065 7	0.065 5	–0.2	±0.1	±3.3
29	0.077 6	0.077 8	+0.2	±0.1	±3.9
30	0.061 3	0.061 3	–0.0	±0.1	±3.1
31	0.072 6	0.072 6	+0.0	±0.1	±3.6
32	0.057 5	0.057 7	+0.2	±0.1	±2.9
33	0.068 2	0.068 3	+0.2	±0.1	±3.4
34	0.054 1	0.054 0	–0.2	±0.1	±2.7
35	0.064 3	0.064 5	+0.2	±0.1	±3.2
36	0.051 1	0.051 3	+0.2	±0.1	±2.6
37	0.060 8	0.061 2	+0.4	±0.1	±3.0
38	0.048 4	0.048 6	+0.2	±0.1	±2.4
39	0.057 7	0.057 7	+0.0	±0.1	±2.9
40	0.046 0	0.045 9	–0.1	±0.1	±2.3

Fluctuating Harmonics - Class A Tests

Purpose of Tests

These tests examine the performance of the Power Analyser when measuring fluctuating harmonics at the Class A waveform short-term limits. A special waveform is used to test the performance of the Analyser against the response of an ideal analyser. The test is designed to detect errors in the Analyser dynamic performance that cannot be detected in a steady state test.

It is assumed that the Analyser is designed in accordance with IEC 61000-4-7: 2002. Rectangular analyser analysis window widths of 10 fundamental cycles (0.2 s) have been assumed for these tests.

Applied Fluctuating Harmonic Waveform

Two waveforms were applied separately to the Analyser. The first waveform consisted of odd harmonics from 3 to 9; all other harmonics and the fundamental were set to zero. The second waveform consisted of odd harmonics from 9 to 33; all other harmonics were set to zero. The nominal phase relationship between the applied harmonics in each waveform was zero. The DC component of the waveform was negligible.

To give fluctuating harmonics, each harmonic was modulated (0 to 100 %) by a waveform with a repeat period of 6.4 s (32 analyser analysis windows at 0.2 s). Each of these modulation waveforms was constructed from two Gaussian waveforms. The first Gaussian caused the fluctuating harmonic to rise from zero to a peak value in approximately 2 s. Having reached a peak, the second Gaussian caused a decay to zero in approximately 0.4 s. Each harmonic was zero for the remaining 4 s of the 6.4 s repeat period.

The modulation waveform for each harmonic was progressively shifted in phase in order to give rise to a distribution in the Analyser results, which can be fitted to an ideal analyser response.

Power Analyser Data Analysis Method

The program was configured to 'EN61000:2001', 'Fluctuating Harmonics', Class-A mode, with a test time of 2 minutes and 30 seconds. The 25 A Peak range of the Analyser was selected.

Using the exported data obtained from the Analyser, an average value for each harmonic was obtained by averaging results from an integer number of modulation cycles (391 analysis windows) for the given harmonic. Maximum values for each harmonic were obtained by finding the maxima of the results over the same period as the average.

Fluctuating Harmonic Results

Due to the measurement method specified for Analysers (IEC 61000-4-7: 2002), the average and maximum harmonic results, in general, have a significant variation between tests for fluctuating harmonic signals. The phase shifting of the harmonic modulators used in the applied calibration signal, as described above, allows the analyser results to be fitted to an ideal analyser response. The fitting allows the verification of the correct operation of the Analyser when used under fluctuating harmonic conditions. The results for harmonics 3 to 9 of the first waveform described above and for harmonics 9 to 33 for the second waveform are given in Table 2. Results at harmonic 9 are available from both of the separate tests as a tie-up measurement. These results have been averaged to give the result shown in Table 2. The uncertainties given in Table 2 are based on a standard uncertainty multiplied by coverage factors of $k = 2.11$ and $k = 2$ for the Average and Maximum results respectively. These factors provide a level of confidence of approximately 95 %.

Table 2, Fluctuating Harmonic Tests

	Average Value as Indicated by an Ideal Analyser				Maximum Value as Indicated by an Ideal Analyser			
Harmonic Number	Nominal Applied	Instrument Error	Target Error	Uncertainty in Instrument Error	Nominal Applied	Instrument Error	Target Error	Uncertainty in Instrument Error
	(A)	(mA)	(mA)	(mA)	(A)	(mA)	(mA)	(mA)
3	2.070	−6	±104	±11	4.140	−6	±207	±26
5	1.026	−2	±51	±6	2.052	−3	±103	±13
7	0.693	+1	±35	±4	1.386	−0	±69	±9
9	0.360	+1	±18	±2	0.720	+0	±36	±5
11	0.297	+1	±15	±2	0.594	−1	±30	±4
13	0.189	+0	±9	±1	0.378	−1	±19	±3
15	0.135	+0	±7	±1	0.270	+1	±14	±2
17	0.119	+0	±6	±1	0.238	+1	±12	±2
19	0.107	+0	±5	±1	0.213	+0	±11	±2
21	0.096	+0	±5	±1	0.193	+1	±10	±1
23	0.088	+0	±4	±1	0.176	+1	±9	±1
25	0.081	+0	±4	±1	0.162	+1	±8	±1
27	0.075	+0	±4	±1	0.150	+0	±8	±1
29	0.070	+0	±3	±1	0.140	+0	±7	±1
31	0.065	+0	±3	±1	0.131	+0	±7	±1
33	0.061	+0	±3	±1	0.123	+0	±6	±1

Fluctuating Harmonics – Step Change Test

Purpose of Tests

According to page 13 of IEC61000-3-2: 2000: Amendment 1:2001-08, for each harmonic order, the Power Analyser should measure the 1.5 s smoothed RMS harmonic current in each analyser analysis DFT time window. These tests assess the Power Analyser's implementation of the 1.5 s low pass filter when a square-wave modulated waveform is applied.

Measurement Method

A fundamental component with a nominal current of 2.3 A RMS was applied to the device together with 3rd, 5th, 7th and 9th harmonics of fluctuating amplitude. All other harmonics were set to nominal zero value. The harmonics were such that their fluctuation gave rise to two distinct amplitude levels at nominally 100 % and 150 % of the Class A limits for each harmonic, as shown in Table 3(a). Following a period of time at one level, which depended on the harmonic number, the amplitude was changed to the second level for an equal period of time, before continuously repeating the pattern. The time spent at each amplitude level for each harmonic is given in Table 3(a) and Table 3(b). The harmonic amplitudes at each level were measured using an appropriate transform.

The program was configured to 'EN61000:2001', 'Fluctuating Harmonics', Class-A mode, with a test time of 2 minutes and 30 seconds. The Power Analyser was configured to perform the measurements on the 10 A Peak range.

The following low-pass filter response in the time domain was assumed:

$$i_t = I_s + [(I_L - I_s).(1 - e^{-\frac{t}{\tau}})]$$

where i_t = current at time t, I_s = current at the start point, I_L = current at the applied level and τ = filter time constant

Using the data obtained from the Power Analyser, the time constant and harmonic driving current were obtained by fitting the data to the equation by method of least squares. The calculated Power Analyser current errors and time constants for each repeat period are given in Table 3(a) and Table 3(b) respectively.

Step Change Test Results

The uncertainty in calculated Power Analyser current error is ± 2 mA. This uncertainty is based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95 %.

Table 3(a), Multi-State Step Change Tests - Current Amplitude Results							
		High Level			Low Level		
Harmonic	Repeat Period (s)	Nominal Applied (A)	Calculated Instrument Current Error (mA)	Target Error (mA)	Nominal Applied (A)	Calculated Instrument Current Error (mA)	Target Error (mA)
3	3	3.450	–4	±173	2.300	–3	±115
5	6	1.710	–3	±86	1.140	–3	±57
7	9	1.155	–1	±58	0.770	–1	±39
9	6	0.600	–1	±30	0.400	–1	±20

The uncertainties in calculated time constant for each harmonic are given in Table 3(b). These uncertainties are based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95 %.

Table 3(b), Multi-State Step Change Tests - Time Constant Results				
Harmonic	Repeat Period (s)	Nominal Time Constant (s)	Calculated Instrument Time Constant (s)	Uncertainty on Calculated Time Constant (ms)
3	3	1.500	1.500	±9
5	6	1.500	1.499	±9
7	9	1.500	1.498	±9
9	6	1.500	1.501	±9

Interharmonic Measurements

Purpose of Tests

According to Section 5.5.1 of EN61000-4-7: 2002 the output (OUT1; see Figure 1 of EN61000-4-7) of the DFT is first grouped to be the sum of the squared intermediate lines (interharmonics) between two adjacent harmonics.

By sweeping a single frequency component across the grouping range of three adjacent harmonics, this test seeks to verify the correct operation of the Power Analyser's software against the algorithm given in EN61000-4-7.

Measurement Method

A fundamental component with a nominal current of 1 A RMS was applied to the Power Analyser together with a higher frequency component of nominal amplitude of 100 mA RMS. The frequency of the component was swept from 450 Hz to 590 Hz in steps of 5 Hz. During these tests, all other harmonics were set to nominal zero value. At each frequency, the results of the Power Analyser were recorded using a 30 second test time. The results recorded are shown in Table 4. A hyphen in Table 4 indicates that the harmonic level is less than 2.5 mA.

The uncertainties in the measurements in Table 4 are as follows:

Uncertainty in applied fundamental current is ± 0.2 mA,
Uncertainty in applied harmonic of nominal 100 mA is ± 0.1 mA,

The column headed "Expected Result" in Table 4 indicates whether the Power Analyser's software reports correctly against the algorithm given in EN61000-4-7.

All uncertainties are based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95 %.

The program was configured to 'EN61000:2001', 'Fluctuating Harmonics', Class-A mode, with a test time of 30 seconds. The Power Analyser was configured to perform the measurements on the 10 A Peak range.

Table 4 - Interharmonic Grouping Verification							
Nominal Component Frequency (Hz)	Nominal Fundamental (A)	Nominal Component Current (A)	Expected Result	Instrument Reading (A)			
				H1	H9	H10	H11
450	1	0.1	✔	0.997 1	0.099 7	-	-
455	"	"	✔	0.997 4	0.099 8	-	-
460	"	"	✔	0.997 0	0.099 8	-	-
465	"	"	✔	0.996 8	0.099 8	-	-
470	"	"	✔	0.996 9	0.099 8	-	-
475	"	"	✔	0.997 3	0.070 5	0.070 6	-
480	"	"	✔	0.997 3	-	0.099 9	-
485	"	"	✔	0.997 2	-	0.099 9	-
490	"	"	✔	0.997 2	-	0.099 9	-
495	"	"	✔	0.997 1	-	0.099 9	-
500	"	"	✔	0.997 0	-	0.099 8	-
505	"	"	✔	0.997 4	-	0.099 8	-
510	"	"	✔	0.997 1	-	0.099 8	-
515	"	"	✔	0.997 3	-	0.099 8	-
520	"	"	✔	0.997 6	-	0.099 8	-
525	"	"	✔	0.996 6	-	0.070 5	0.070 6
530	"	"	✔	0.997 1	-	-	0.099 9
535	"	"	✔	0.996 7	-	-	0.099 9
540	"	"	✔	0.997 0	-	-	0.099 9
545	"	"	✔	0.997 3	-	-	0.099 9
550	"	"	✔	0.996 8	-	-	0.099 8
555	"	"	✔	0.997 1	-	-	0.099 8
560	"	"	✔	0.997 0	-	-	0.099 8
565	"	"	✔	0.997 1	-	-	0.099 8
570	"	"	✔	0.996 9	-	-	0.099 7
575	"	"	✔	0.997 1	-	-	0.070 5
580	"	"	✔	0.997 1	-	-	-
585	"	"	✔	0.996 7	-	-	-
590	"	"	✔	0.997 2	-	-	-

END OF MEASUREMENTS