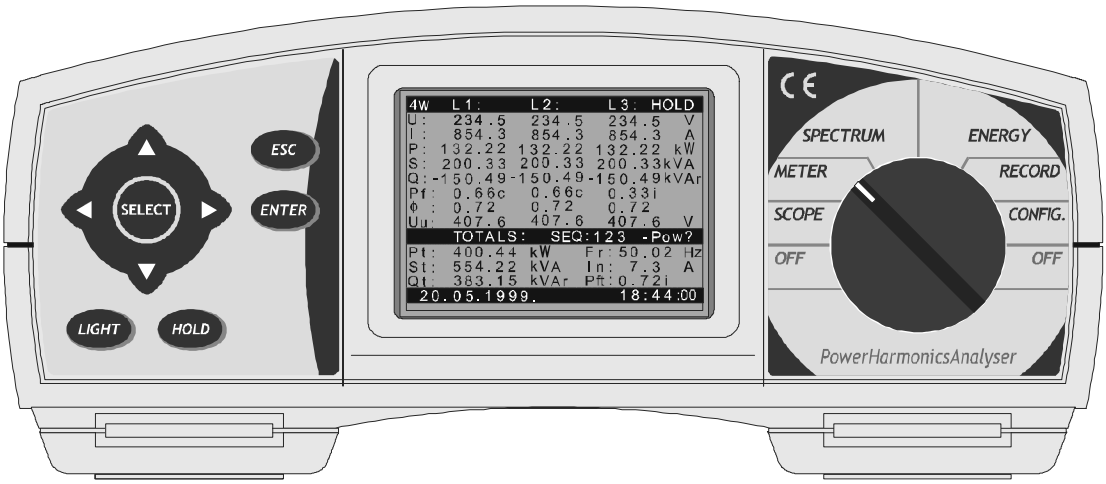
User manual
Power Harmonics Analyzer



Supplier:	Nieaf-Smitt bv Vrieslantlaan 6 3526 AA Utrecht Holland P.O. box 7023 3502 KA Utrecht
	Telephone: ++ 30 288 13 11 Fax.: ++ 30 289 88 16
Specifications of the equipment:	Power Harmonics Analyzer PHA 3300
Specifications of the user manual:	Date: 25-01-2011 Number:561.144.075 Ref.: 002

Table of contents

POWER HARMONICS ANALYSER

The Power Harmonics Analyser is a portable multifunction instrument for measurement and analysis of three-phase power systems.

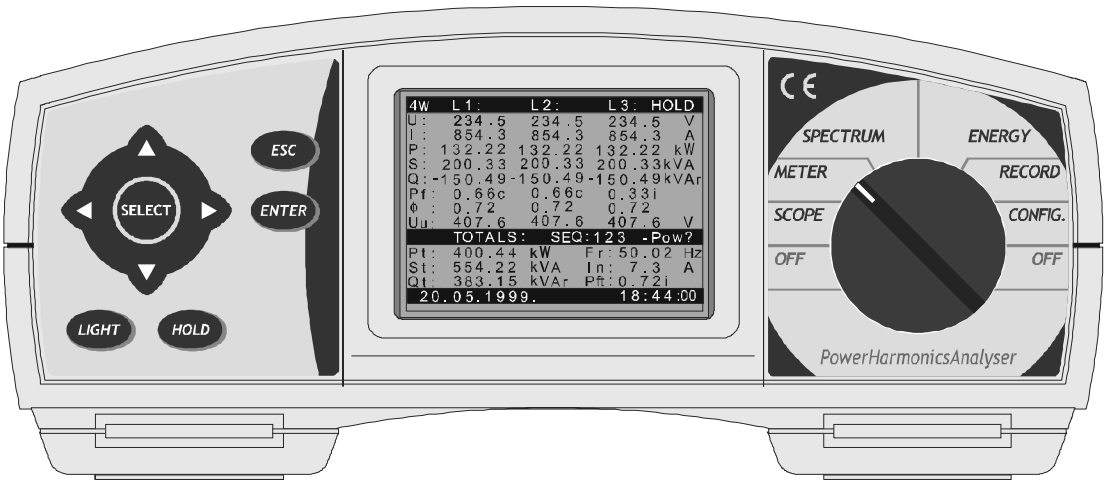


fig. 1

Main features

- Comprehensive real time monitoring, recording and analysis of 3φ power systems.
- Wide range of functions:
  - True rms Voltage
  - True rms Current
  - Power (Watt, var and VA)
  - Power Factor
  - Energy
  - Power Scope
  - Harmonic Analysis
- Monitoring of Voltage and power supply interruptions with analysis of recorded data.
- In recording mode, measured values are stored in memory for later analysis.
- Minimum, average & maximum value calculations for recorded quantities, with various pre-formatted reports.
- Oscilloscope mode for displaying waveforms, both in real time and for stored waveform analysis.
- Harmonic distortion analysis up to 63rd harmonic, both on line and on recorded data.
- Energy monitoring and analysis.
- Internal rechargeable batteries.
- RS232 communication port for connection to a PC.
- Windows software for data analysis and instrument control.

SAFETY CONSIDERATIONS

GENERAL

To ensure operator safety while using the Power Harmonics Analyser, and to minimise the risk of damage to the instrument, please note the following general warnings:

⚠ **The Instrument has been designed to ensure maximum operator safety. Use in a fashion other than as specified in this Manual may increase the risk of harm to the operator!**

⚠ **Do not use the instrument and/or any accessories if there is any damage visible!**

⚠ **The Instrument contains no user serviceable parts. Service or calibration must only be carried out only by an authorized dealer!**

⚠ **All normal safety precautions MUST be taken in order to avoid risk of electric shock when working on electric installations!**

⚠ **Only use approved accessories, which are available from your distributor!**

APPLICABLE STANDARDS

The Power Harmonics Analyser is designed in accordance to the following European standard:
Safety • EN 61010-1

Electromagnetic compatibility (noise and immunity):

- EN 50081 –1
- EN 50082 –1

Measurements according to European standard:

- EN 50160

SECTION I
GENERAL INFORMATION

1. INTRODUCTION

This manual provides information for the connection, operation, programming, data analysis and maintenance of the Power Harmonics Analyser (shown in *fig. 1*).

The manual is divided into five sections, each covering a particular aspect of the operation of the Power Harmonics Analyser.

	Topic
I	General information
II	Internal Operation
III	Meter Operation
IV	Connection to Power System
V	PC Software
VI	Theory of operation

2. DESCRIPTION

2.1. FRONT PANEL

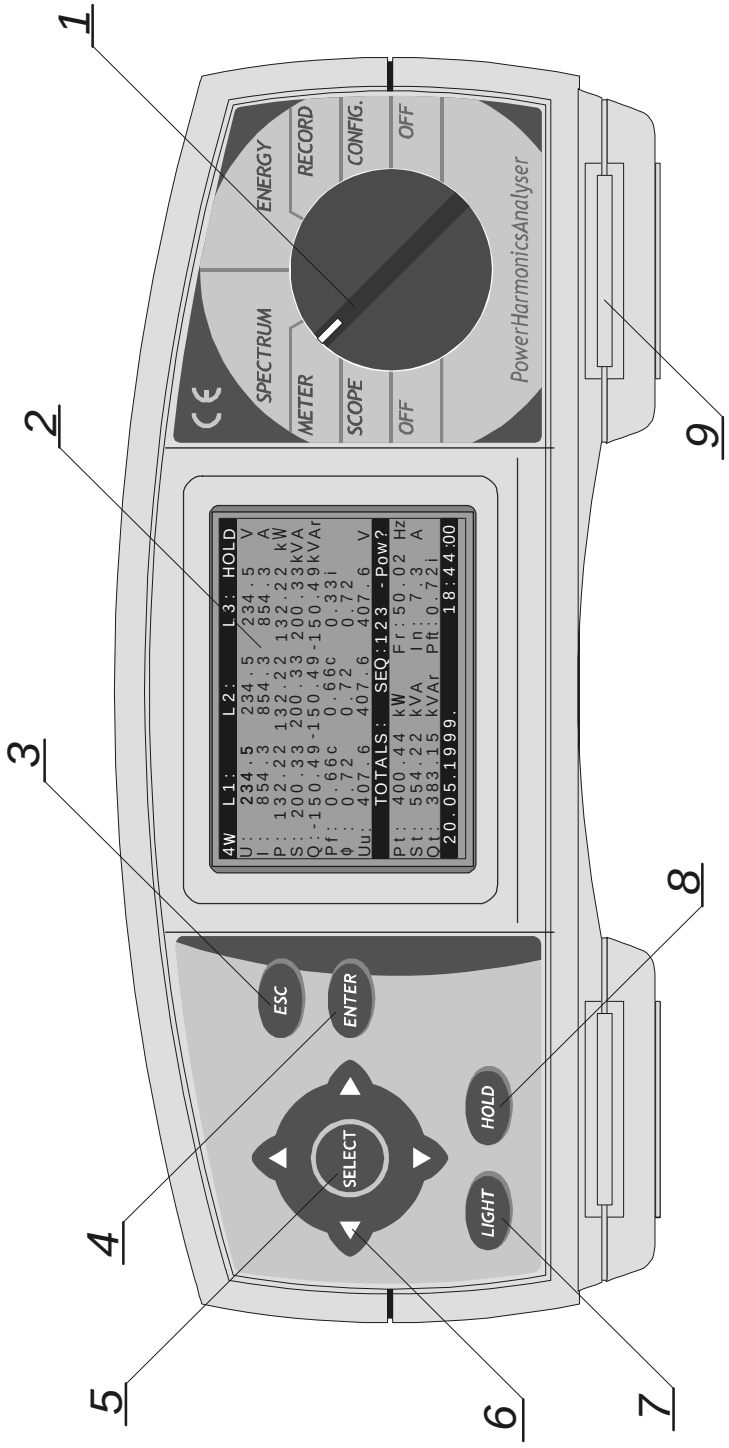


fig. 2: Front panel

Front Panel Layout:

*1..... **FUNCTION switch**, selects one of seven functional/operating menus:*

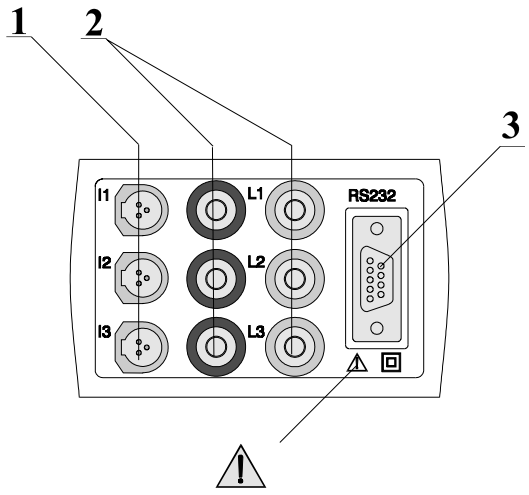
- ***OFF*** *Power OFF*
- ***CONFIG*** *Instrument configuration menu*
- ***RECORD*** *Recording menu*
- ***ENERGY*** *Energy measurement*
- ***SPECTRUM*** *Harmonic analysis menu*
- ***METER*** *Basic power, current & voltage measurements*
- ***SCOPE*** *Waveforms display & control*

*2..... **LCD*** *Graphic display with LED backlight, 160x116 pixels.*
*3..... **ESC key:*** *To exit any procedure*
*4..... **ENTER key:*** *To confirm new settings, start recording procedure*
*5..... **SELECT key:*** *Enable selected signals*
*6..... **ARROW keys:*** *Move cursor and select parameters*
*7..... **LIGHT key:*** *LCD backlight ON/OFF*
(Backlight automatically turns OFF after 30 sec. if no key action occurs)

LIGHT + ↑ *Increase display contrast*
LIGHT + ↓ *Decrease display contrast*

*8..... **HOLD key** :* *Display screen is temporary frozen*
(SCOPE ,METER and SPECTRUM functions only)
9..... ***BELT slot**,* *For attachment of a carry strap.*

2.2. CONNECTOR PANEL (on side of Meter)



- Use safety test leads only!
- Max. permissable voltage between voltage input terminals and ground is $300V_{rms}$

Max. permissable voltage between voltage input terminals is $600V_{rms}$

fig. 3: Connector panel

Connector Panel Layout:

1..... Current Clamp-on CTs/Transformers (I_1, I_2, I_3) input terminals
2..... Voltage (L_1, L_2, L_3) input terminals
3..... RS 232 connection (for connection of the Power Harmonics Analyser to a PC)

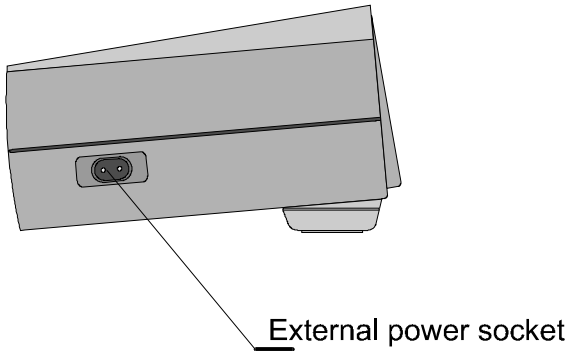


fig. 4: External power socket

2.3. BOTTOM VIEW

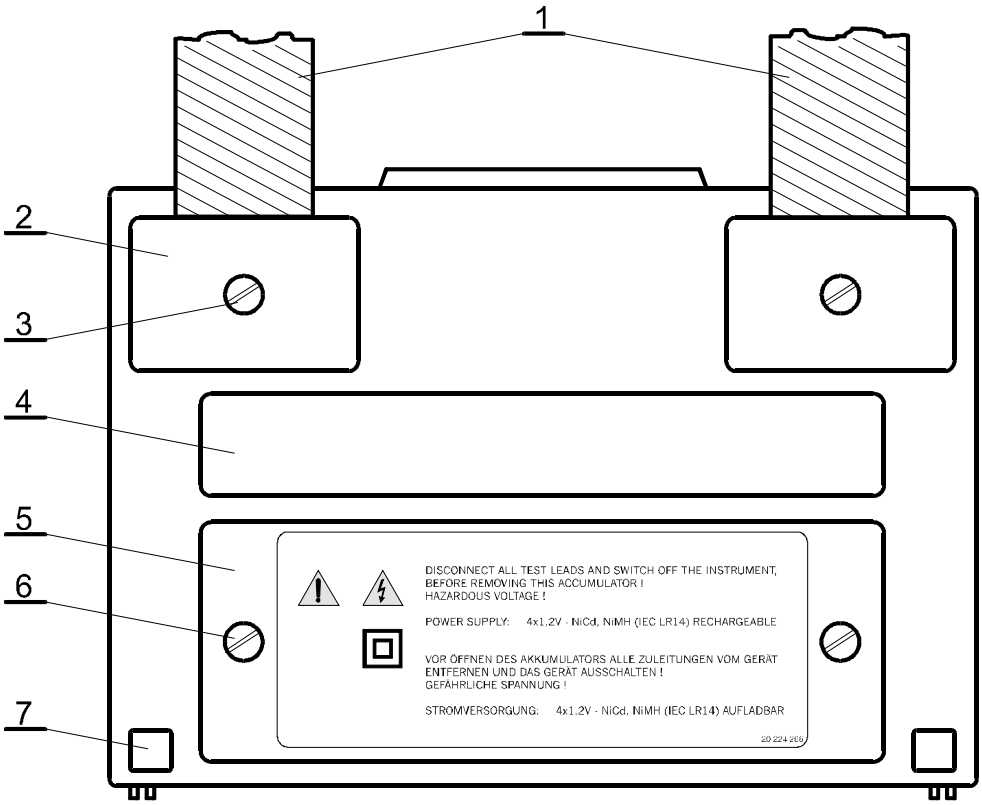


fig. 5: Bottom view

Bottom View Layout:

1 Nylon strap (allows the instrument to be slung round the neck).
2 Plastic cover (fixes nylon strap to the instrument). There is a screw under this cover that needs to be unscrewed when opening the instrument for service or calibration purposes.

The Instrument contains no user serviceable parts.
Service or calibration must only be carried out only by an authorized dealer

3 Screw (unscrew to remove carrying strip or to open the instrument).
4 Label with measurement ranges.
5 Battery/fuse compartment cover.
6 Retaining screw (unscrew to replace batteries or blown fuse).
7 Rubber foot.

2.4. *STANDARD ACCESSORIES*

Current probes:

- Current clamp-on CTs, model S 1000A/ 1V, 3 off
- Current transformers (Optional)

Voltage cables, Current cables:

- Probe tips, 3 off
- Alligator clips. 4 off
- Voltage measurement cables, 6 off
- Mains cable
- RS 232 cable
- Soft carrying bag
- Instruction manual
- Product verification data
- Warranty declaration

Windows PC software:

- *PC analysis and control software package*

2.5. OPTIONAL ACCESSORIES

See attached sheet for a list of optional accessories that are available on request from you distributor.

3. SPECIFICATIONS

The instrument's technical specification below details the performance standard or limit to which the instrument has been designed and tested.

3.1. INPUTS

3.1.1 AC VOLTAGES

The instrument has a three-phase AC voltage input (3 differential inputs, $L_1 - N_1$, $L_2 - N_2$, $L_3 - N_3$).
Voltage measurement is direct with internal voltage dividers.
There are no internal fuses in the voltage inputs.

- ⚠ **CAT III 600V, 300V to GND**
- Input range: 10 - 550 Vrms (0.02 U_n - U_n)
- Permissible overload 600 Vrms
- Resolution: 0.1V
- Accuracy: ± 0.5% of reading ± 2 digits
- Crest factor max. 1,4
- Frequency range : 43..68 Hz fundamental

3.1.2 AC CURRENTS

The instrument has three AC current inputs, suitable for Clamp-on CTs or other current sensors.

- Input range: 0 - 1 Volt rms (0 - I_n)
  Equivalent to 0 - 1000 Amp with the standard Clamp-on CT.
- Resolution: 0.3mV (0.3Amp with the standard Clamp-on CT.)
- Accuracy: ± 0.5% of reading ± 2 digits plus current transformer accuracy
- Crest factor 2.5
- Maximum permissible overload 150% I_n (sinusoidal current)
- Maximum input voltage 1 Vrms
- Accuracy of standard clamp: 1%
  (20 Amp – 1000 Amp)
- ⚠ **Use double insulated minimum CAT III 600V Clamp-on CTs and/or current transformers**

3.1.3 REFERENCE CONDITIONS

AC voltage for power measurements	0.02 U_n … U_n
AC current	0 … I_n
Power factor	four quadrants (1.00_{cap} … 0.00 … 1.00_{ind})
Frequency	45 … 65 Hz
Waveform	Sinusoidal AC voltage and current
Distortion factor	< 2%
Auxiliary power supply	230V ± 10%
Ambient temperature	20°C ± 3°C
Humidity	60% ± 15%

3.2. OUTPUTS

3.2.1. Communication

RS232 serial interface for connection to a PC, fully opto isolated. Selectable 2400 - 57,600 baud. 9 pin D-type connector. Communication cable supplied.

3.2.2. Display

Graphic Liquid Crystal Display with LED backlight, 160x116 dots resolution.

3.3. POWER SUPPLY

3.3.1. AC power supply

Operating range: 230VAC + 10% -20%, overvoltage category III, 45 - 65 Hz, 8 VA

3.3.2. DC power supply

Internal 4 x 1.2V NiCd or NiMh rechargeable IEC LR14 batteries provide full operation for up to 5 hours.
Internal battery charger, charging time approx. 10 hours.

3.4. NON - VOLATILE MEMORY

2048 Kbytes SRAM, battery backed.

3.5. HARMONICS MEASUREMENT

The instrument computes harmonics on signals sampled with an A/D converter.

Table 1 : Limits of error and resolution in Harmonics measurement:

Range	**Limits of error**		**Resolution**
I_r, U_r	THD	HD	on LCD and PC
2 … 100%	0.2% x U_r/U (I_r/I)	0.2% x U_r/U (I_r/I)	0.1%

Note: THD Total Harmonic Distortion
HD Harmonic Distortion
U_r U_{range}
I_r I_{range}

3.6. DIGITAL HARDWARE SPECIFICATIONS

A/D conversion 14 bit with 128 samples per channel per period (43 - 68 Hz).

3.7. GENERAL SPECIFICATIONS

Working temperature range	-10°C … +45°C
Storage temperature range	-20 … 70°C
Max. humidity	85%RH (0÷40°C)
Pollution degree	2
Protection classification	double insulation
Overvoltage category	Voltage inputs: CAT III 600V, 300V to gnd AC power supply CAT III 300V
Protection degree	IP 44
Dimensions	265 x 110 x 18.5 mm
Weight (without accessories)	2kg

3.8. MAINTENANCE

3.8.1. Batteries

⚠ **Instrument contains rechargeable NiCd or NiMh batteries. Do NOT replace with alkaline cells. These batteries should only be replaced with the same type as defined on the battery cover label or in this manual.**

⚠ **Hazardous voltages exist inside this Instrument. Disconnect all test leads, remove the power supply cable and switch off instrument before removing battery compartment cover.**

If it is necessary to replace batteries, all four MUST be replaced. Ensure batteries are installed with the correct polarity; incorrect polarity can damage the batteries and/or the instrument.

There may exist special environmental regulations concerning the disposal of batteries. These must be followed.

⚠ **In case of blown battery fuse (F1), this should be replaced with the same type as defined on the label close to it.**

3.8.2. Cleaning

To clean the surface of instrument, use a soft cloth slightly moistened with soapy water or alcohol. Then leave the instrument to dry totally before use.

- ***Do not use liquids based on petrol or hydrocarbons!***
- ***Do not spill cleaning liquid over the instrument!***

3.8.3. Periodic calibration

To ensure correct measurement, it is essential that the instrument be regularly calibrated. If used continuously on a daily basis, a six monthly calibration period is recommended, otherwise annual calibration is sufficient.

3.8.4. Service

For repairs under warranty, or at any other time, please contact your distributor.

Manufacturer's address:

Nieaf-Smitt B.V.
Vrieslantlaan 6
3526 AA Utrecht
The Netherlands

Tel: +31(0) 30 2881311
Fax: +31(0) 30 2898816
E-mail sales@nieaf-smitt.nl

The Instrument contains no user serviceable parts.
Service or calibration must only be carried out only by an authorized dealer!

SECTION II
INTERNAL OPERATION

1. INTRODUCTION

This section contains technical information on the internal operation of the Power Harmonics Analyser, including descriptions of measuring methods and recording principles.

2. MEASUREMENT METHODS

Measurement methods are based on the digital sampling of the input signals. Each input (3 voltages and 3 currents) is sampled 128 times in each input cycle. Duration of this input cycle depends on the frequency at the synchronization input (one of the 3 voltage inputs or a current input). At 50 Hz, the input cycle period is 20ms.
Basic measured values are calculated at the end of each sampling period and the results are available on the display or are recorded.
FFT based results are only calculated on every 8th input cycle (every 160ms@50Hz).
The following equations are used for computing the given quantities.

Basic calculations

Parameter	Equation for calculation	Unit	Formula N°
Phase voltage	$U_x = \sqrt{\frac{1}{128}\sum_{i=1}^{128} u_{x_i}^2}$	V	[1]
Phase current	$I_x = \sqrt{\frac{1}{128}\sum_{i=1}^{128} i_{x_i}^2}$	A	[2]
Phase active power	$P_x = \frac{1}{128}\sum_{i=1}^{128} u_{x_i} * i_{x_i}$	W	[3]
Phase to phase voltage	$U_{xy} = \sqrt{\frac{1}{128}\sum_{i=1}^{128} \left(u_{x_i} - u_{y_i}\right)^2}$	V	[4]
Neutral conductor current	$I_0 = \sqrt{\frac{1}{128}\sum_{i=1}^{128} (i_{1i} + i_{2i} + i_{3i})^2}$	A	[5]

Additional calculation (using basic values)

Phase apparent power	$S_x = U_x * I_x$	VA	[6]
Phase reactive power	$Q_x = \sqrt{S_x^2 - P_x^2}$	var	[7]
Phase power factor	$PF_x = \frac{P_x}{S_x}$		[8]
Phase voltage crest factor	$Q_{x_{cr}} = \frac{U_{x_{max}}}{U_x} * 100$		[18]
Phase current crest factor	$I_{x_{cr}} = \frac{I_{x_{max}}}{I_x} * 100$		[19]

Additional calculation (using FFT transformation)

Phase voltage-current angle	$\phi = \phi_i - \phi_u$ ϕ_i, ϕ_u are calculated by FFT VI angle for the fundamental component		[9]
Phase voltage THD	$thd_{U_x} = \frac{\sqrt{\sum_{n=2}^{63} hn_{U_x}^2}}{h1_{U_x}} * 100$	%	[10]
Phase current THD	$thd_{I_x} = \frac{\sqrt{\sum_{n=2}^{63} hn_{I_x}^2}}{h1_{I_x}} * 100$	%	[11]
Phase voltage individual harmonics	$Hn_{U_x} = \frac{hn_{U_x}}{h1_{U_x}} * 100$	%	[12]
Phase current individual harmonics	$Hn_{I_x} = \frac{hn_{I_x}}{h1_{I_x}} * 100$	%	[13]

Total values

Total active power	$P_t = P_1 + P_2 + P_3$	W	[14]
Total reactive power	$Q_t = Q_1 + Q_2 + Q_3$	var	[15]
Total apparent power	$S_t = \sqrt{P_t^2 + Q_t^2}$	VA	[16]
Total power factor	$Pf_t = \frac{P_t}{S_t}$		[17]

In a 3φ systems with a normal 3 wire connection, the following values are not available for displaying and recording:

- Neutral conductor current
- Phase voltage-current angle
- Phase power factor

SECTION III
POWER HARMONICS ANALYZER
OPERATION MANUAL

1. GENERAL

This section describes how to operate and programme the instrument.

The instrument front panel consists of a graphic LCD display, nine keys and an eight position rotary switch. Measured data and current instrument status are shown on the display.

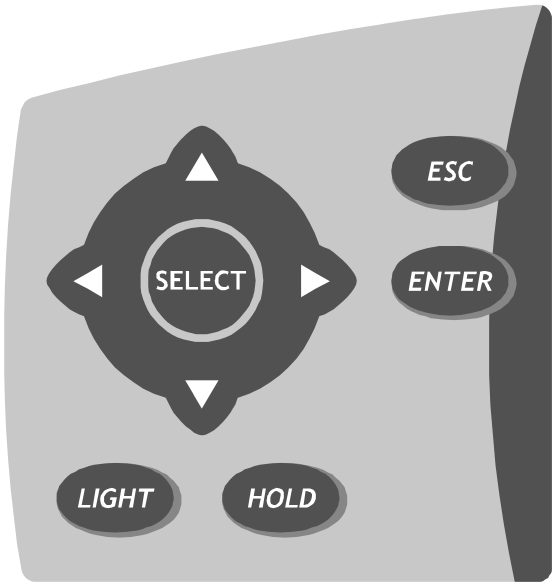


fig. 6: Keypad

ESC	To exit any procedure
ENTER	To confirm new settings, start recording procedure
SELECT	Enable selected signals
ARROW	Move cursor and select parameters
HOLD	Display screen is temporary frozen (SCOPE, METER and SPECTRUM functions only)
LIGHT	LCD backlight ON/OFF Backlight will automatically turn OFF 30 seconds after the last key operation
LIGHT + UP	Increases display contrast
LIGHT + DOWN	Decreases display contrast
HOLD	Display Freeze In SCOPE, METER and SPECTRUM functions only

NOTE: *Throughout these instructions the '**up arrow**' key is called the '**UP key**', the '**right arrow**' key the '**RIGHT key**', the '**down arrow**' key the '**DOWN key'** and the '**left arrow**' key the '**LEFT key'**.*

One of seven functional/operating menus can be selected with the rotary selector switch:

OFF	Power OFF
CONFIG	Instrument configuration menu
RECORD	Data Logging (Recording) menu
ENERGY	Energy measurement
SPECTRUM	Harmonic analysis menu
METER	Basic power, current & voltage measurements
SCOPE	Waveforms display & control

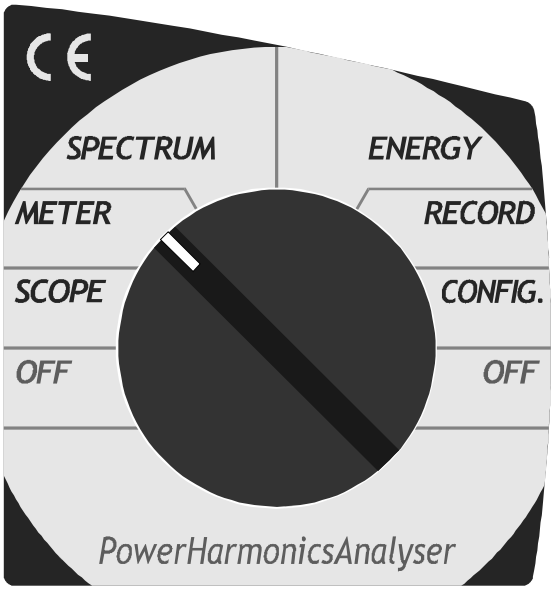


fig. 7: Instruments rotary selector switch

The instrument's main design function is the logging of various parameters on power distribution systems. Logging functions are selected on the right side of the rotary switch.

Recording mode	**OFF**	All settings are saved. Warning given if recording is in progress
	CONFIG	General configuration; Submenus cover specific functions
	RECORD	Data logging and monitoring
	ENERGY	Total and subtotal cumulative register (energy counters)

Further information on the functions available in RECORDING Mode is available under 'THEORY OF OPERATION'.

The instrument can also be used for real time measurement, available on the left side of the rotary switch. These function are independent of recording status.

Real time measurements	**SPECTRUM**	Harmonic Analysis
	METER	Basic measurements on three phase systems
	SCOPE	Oscilloscope displays of measured waveforms
	OFF	All settings are saved. Warning given if recording is in progress

2. OFF

Selecting **OFF** turns the instrument OFF after 2 seconds. All current settings and set parameters are saved during this period in non-volatile memory. If switching OFF occurs while the instrument is set for recording, this is treated as a POWER BREAK and the date & time of Power OFF is saved. This will also occur if the instrument loses its power supply while recording (see section II.3.5 Power Break Recording). If the instrument is set for recording, this will be indicated on the display irrespective of the position of the rotary Selector Switch:

- **Rec.On:** Recording in progress
- **Rec.Wt:** Waiting to start recording
- **SEND:** Instrument is sending data to a PC
- **HOLD:** Display contents temporarily frozen
  In SCOPE, METER and SPECTRUM functions only

3. CONFIG

Use this menu to set all parameters for Recording and Real time measurement.
The main screen in the **CONFIG** menu includes instrument details (Model number, software version & serial number) and shows date and time on the bottom line. From this main screen, various configuration sub-menus can be accessed, allowing instrument parameters, measurement conditions and settings to be changed.
The **HOLD** function is ignored in this menu.
Battery status is displayed at bottom of the display (see *fig.8*).
The legend "**EXTR**" is shown if the Instrument is being powered from the mains rather than from the battery.

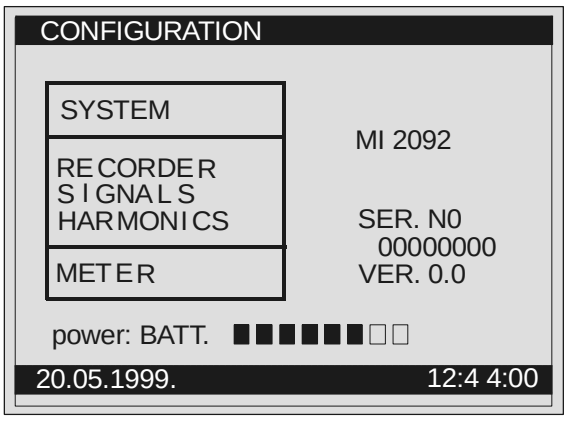


fig. 8

The main **CONFIG** menu consists of five items. Use the **UP** and **DOWN** keys to highlight the appropriate item, then press the **ENTER** key to select it.

3.1. PASSWORD

All programming functions and recorder settings (including the starting & stopping data logging) are password protected. Unless the password is entered, the various settable parameters & functions can only be viewed. In all configuration sub-menus, pressing any edit key (**UP, DOWN, LEFT, RIGHT, SELECT, ENTER**) will activate password input procedure. The password must be entered before the **SYSTEM** sub-menu is selected.

PASSWORD: * * * *

Default password
LEFT, SELECT, RIGHT, ENTER

The password is automatically cleared 5 minutes after the last key operation.

3.2.SYSTEM sub-menu :

This sub-menu allows setting of the password, the serial port baud rate and the instrument date & time. The fourth choice is to totally reinitialise the Instrument.

CHANGE PASSW.
SER. PORT RATE
DATE/TIME
SYSTEM REINIT.

Use **UP** or **DOWN** keys to select the required menu item, then press the **ENTER** key.

CHANGE PASSW Enter a new four key combination and repeat it for confirmation. (The LCD key is not a valid password key)

SER PORT RATE Set the baud rate for serial communication port by using **SELECT** key. (from 2400 to 57,600 baud)

DATE/TIME Use the **LEFT** or **RIGHT** key to select between Date and Time and the **UP** & **DOWN** keys to set a new date or time. Only valid date/time values will be accepted.

Press **ENTER** to confirm the settings or **ESC** to cancel any changes.

SYSTEM REINIT Clears all settings and sets defaults values as below.

- Recorder START/STOP : MANUAL
- Statistic: ON
- Periodic: ON
- Anomalies: ON, fixed
- Main IP: 1 min
- Power sub IP: 1
- Nominal voltage: 230 V
- Up/Down limits: 10 %
- Buffer mode: Circular

- Selected channels: none
- Selected harmonic: none
- Voltage multiplier(K): 1
- Current range: 1000A
- Connection: 4w
- Sync. frequency: 50 Hz
- Sync. input: AUTO
- Serial port rate: 57600

3.3. RECORDER (Data Logging) sub-menu

Use this sub-menu to set Data Logging parameters and log START/STOP conditions.
Note that actual starting or stopping can only be effected from the main **RECORD** menu.

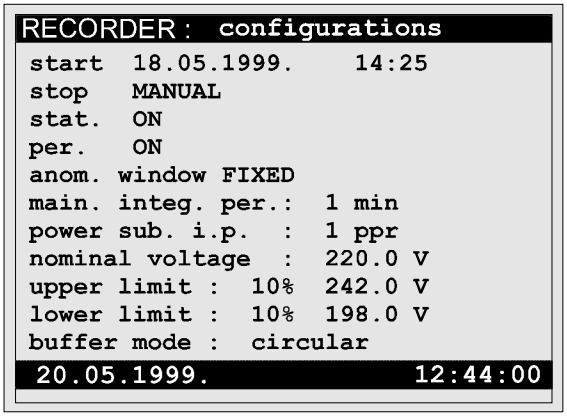


fig. 9

Use **UP** or **DOWN** key to select the appropriate parameter.

START and **STOP** There are two ways of starting and stopping recording.

In **Manual** mode, recording starts immediately if Periodic Recording is OFF.
If Periodic Recording is ON, there is a “null” seconds delay.
STOP in manual mode is immediate.

In **Auto** mode, START and STOP occur at user preset dates and times.
Recording can be stopped manually at any time.
Use **SELECT** key to toggle between **MANUAL** and **AUTO** mode.
In **AUTO** start/stop, use **LEFT** or **RIGHT** keys to select between Date and Time and the **UP** & **DOWN** keys to set a new date or time.
Only valid date/time values will be accepted.

STAT. and **PER.** **STAT**. Statistical Analysis
PER. Periodic Analysis
Use the **SELECT** key to enable (ON) or disable (OFF) the selected function.

ANOM.WINDOW Recording of Voltage Anomalies

Use the **SELECT** key to toggle between Disable (OFF), FIXED Window or VARIABLE Window recording.

In **FIXED** window mode, the window (and the Upper & Lower Limits) is set around the nominal voltage and remains fixed during recording session.

In **VARIABLE** window mode, the window (and the Upper & Lower Limits) is set around an average voltage dynamically calculated. Use the **LEFT** and **RIGHT** keys to adjust the averaging period for calculating new values of average voltage (1 to 900 sec).

Voltage Anomaly recording is only available for those voltages selected for recording (see 3.2.4 SIGNALS) even if Periodic Analysis is disabled. If no voltage is selected, there will be no logging of Voltage Anomalies.

MAIN INTEGR.PER.

Integration (time) period for Periodic Analysis.
Use the **LEFT** and **RIGHT** keys to set the integration period (between 1 second and 30 minutes).

POWER SUB.I.P. Averaging sub period for power measurement. (Power sub IP)
Used in Periodic Analysis to average readings (see, section VI PERIODIC ANALYSIS and the accompanying figure). Settable between 1 and 20 mains cycles.
Use the **LEFT** and **RIGHT** keys to set the required value.

NOMINAL VOLTAGE

The nominal voltage used as a reference in Voltage Anomaly recording.
In **FIXED** window mode, this is the actual voltage used.
In **VARIABLE** window mode, this is the start value of voltage, later modified to the average value of voltage during the previous Integration Period while recording.
Use the **LEFT** and **RIGHT** keys to set the required nominal voltage (from 58.0 V to 450.0 V).

UPPER and **LOWER** limits

These are the limits which define the pass window for Voltage Anomaly recording. Any voltage value outside the specified limits is detected and stored as an anomaly.
Use the **LEFT** and **RIGHT** keys to set the required limit (1% to 30% of nominal voltage).

BUFFER MODE The data storage in the data logging (recorder) function can be performed in two ways: LINEAR or ROLLOVER.

In **Linear** mode, recording stops when the memory is filled.

In **Rollover** mode, recording only stops when the auto stop date/time is reached, or when manually stopped.
Once memory is filled, the oldest data is over-written.

Neither mode will affect any memory allocated for Statistical Analysis.

Press **ENTER** to confirm the new settings or **ESC** to cancel.
Starting or Stopping of Data Logging is effected from the RECORD menu.

3.4. SIGNALS and HARMONICS sub-menus

These menus allow selection of signals, harmonics and calculated parameters for storage while Data Logging (recording). A maximum of 64 signals can be selected; the number of free locations is shown in the upper right corner of the display.

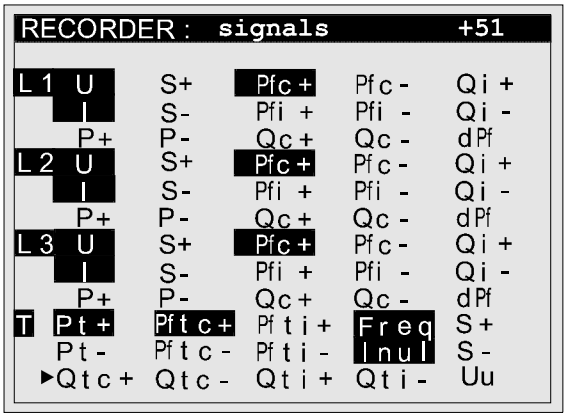


fig. 10: Signal Sub-menu

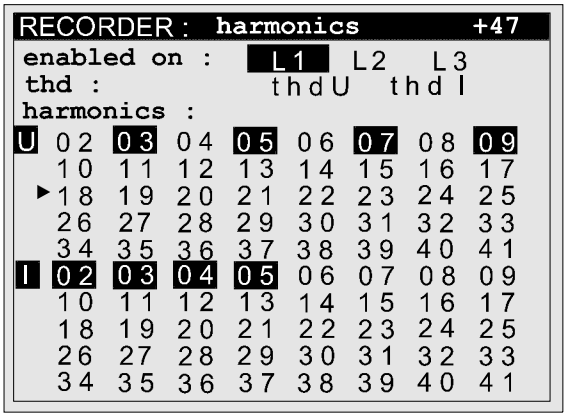


fig. 11: Harmonics Sub-menu

Use **LEFT**, **RIGHT**, **UP** and **DOWN** keys to select the required signal. Enable or disable the signal for recording with the **SELECT** key.

Signals sub-menu Select per-phase and/or total 3φ values.
Selecting a voltage signal U will also automatically enable logging of Voltage Anomalies for that phase (if Voltage Anomaly recording mode is selected as **FIXED** or **VARIABLE**).

Harmonics sub-menu The selected harmonics are valid for all the selected phases (L_1, L_2, L_3 as shown at the top of the screen).
It is not possible to set different combinations for individual phases.
Selecting one or more harmonics will automatically select THD measurement.

Press **ENTER** to confirm the new settings or **ESC** to cancel.

3.5. METER sub-menu

This menu allows setting of various input parameters. These parameters are used for calculating the true rms values of all measured and calculated quantities, for scaling input signals and for synchronisation.

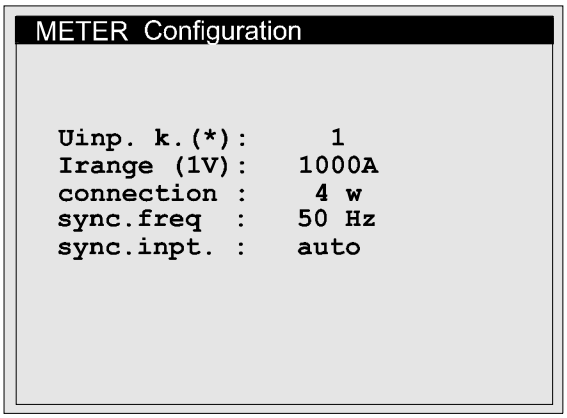


fig. 12: Meter Configuration Sub-menu

Use the **UP** and **DOWN** keys to select the required parameter.

$U_{inp.K}$.(*) Scaling factor for voltage inputs.
This allows for external voltage transformers or dividers that may be used and ensures that readings are related to the primary.
e.g. for 11kV/110V, the multiplication factor must be set to 100.
Use the **LEFT** and **RIGHT** keys to set $U_{inp.K}$. (from 1 to 130).
Standard value is 1.

I_{range} (1V) Scale factor for current inputs.
Defines the current equivalent to a 1V input signal.
Use the **LEFT** and **RIGHT** keys to set I_{range} (1V) (1A to 24kA).
Standard value is 1000A.

NOTE: Settings for $U_{inp.K}$. and I_{range} affect all displayed values (powers, energies, harmonic components, etc).

Connection Defines the method of connecting the Instrument to the 3φ systems:

4w 3φ 4 wire system (with a Neutral conductor).
All voltage and current inputs are used.

3w 3φ 3 wire system (without Neutral conductor)
3 CTs used.

AARON 3φ 3 wire system (without Neutral conductor)
(also known as the '2 wattmeter method')
2 CTs used.

Sync.freq. Default mains frequency for input cycle period/scanning.
It is ignored if the instrument detects a valid synchronisation frequency on the selected sync. input.

Sync.inp. Default synchronisation input.
Use fixed input (L_1, L_2, L_3, I_1) for synchronisation or select AUTO mode (automatic scanning for a valid sync. input).

Press **ENTER** to confirm new settings or press **ESC** to cancel.

4. RECORDER (Data Logging)

Use this function to display the present data logging (recording) status and set the main Data Logging parameters.
Recording can be started or stopped from this screen.
To START or STOP Data Logging:

Press **SELECT** key. The password entry screen is opened.
Enter the password.
After confirming the password, press **ENTER** to start or stop Data Logging (depending on current status).
If START is selected, the instrument checks the currently set recording parameters before starting to log data.

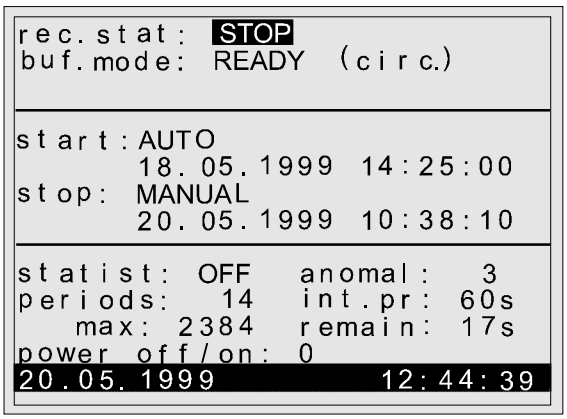


fig. 13: Recorder (Data Logging) Menu

rec.stat. Present recorder status:

WAIT	Recorder (in AUTO mode) is waiting for start date & time
RUN	Recorder is running
STOP	Recorder (in AUTO mode) has been stopped manually. Recording aborted.
COMPLETE	Recording completed

buf.stat. Present recorder memory status:

EMPTY	No data in memory
READY	Data present; awaiting download
SAVED	Data present; previously downloaded

Buffer operating status/mode:

lin.	Memory in Linear mode
circ.	Memory in Roll-over mode
cir./laps	Memory in Roll-over mode, current Lap number

start: If the instrument is in **Rec.Wait** mode and the memory is empty, the programmed START date & time is displayed.
If instrument is in **Rec.Run** mode, the actual recording start date & time (as opposed to programmed) is displayed.

stop: If the instrument is in **Rec.Wait** or **Rec.Run** mode, the programmed STOP date & time is displayed.
If the instrument is in **Rec.Stop** or **Rec.Complete** mode, the actual recording stop date & time (as opposed to programmed) is displayed.
Under certain circumstances, the instrument also displays the reason for stopping the recording:

MANUAL BREAK	Manual stop in AUTO stop mode
END OF MEM.	Memory full (in linear memory mode)

statist. Statistical Analysis enabled (ON) or disabled (OFF).

anomal. The number of detected and saved Voltage Anomalies.
If currently in a Voltage Anomaly, a blinking arrow points to the number.

For Periodic Analysis, there are four further information lines:

periods. Number of recorded periods from start of data logging.

int.pr. Current integration period (IP) in seconds

max. Aprox max. number of periods that can be saved (in Linear Buffer mode only)

remain Remaining time in the current integration period

power N° of power ON/OFF events during the current recording period.

5. ENERGY

This function displays the various energy registers.

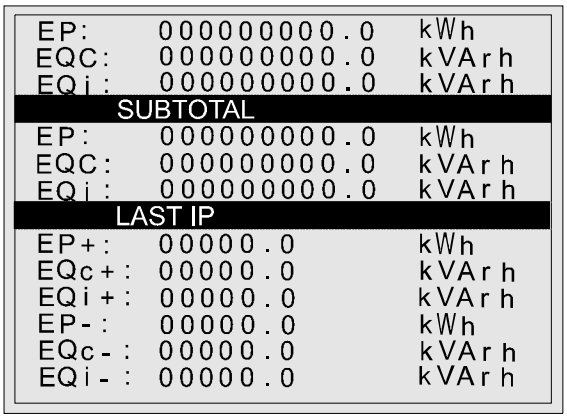


fig. 14: Energy Registers

- Top three lines: **Total** cumulative registers of

Active energy	**Ep**	in kWh
Reactive capacitive energy	**EQC**	in kvar
Reactive inductive energy	**EQi**	in kvar

- SUBTOTAL lines: **Subtotal** cumulative registers of

Active energy	**Ep**	in kWh
Reactive capacitive energy	**EQC**	in kvar
Reactive inductive energy	**EQi**	in kvar

To reset the Total and / or Subtotal registers:

1. Press **SELECT** key. The password entry screen is opened.
2. Enter the password
3. After confirming the password, press **ENTER** to reset the **Subtotals** or **ESC** to quit.
4. After resetting subtotals, press **ENTER** to reset the **Totals** or **ESC** to quit.

- LAST IP lines: Display energy in last integration period (if data logging is active):

Active positive energy	**Ep+**	in kWh
Reactive positive capacitive energy	**EQc+**	in kvar
Reactive positive inductive energy	**EQi+**	in kvar
Active negative energy	**Ep+**	in kWh
Reactive negative capacitive energy	**EQc+**	in kvar
Reactive negative inductive energy	**EQi+**	in kvar

NOTE: At least one signal from Signal Sub-menu (*fig. 10*) and Periodics ON from Configuration Sub-menu (*fig. 9*) must be selected.

6. SPECTRUM (Harmonic Analysis)

This function displays the results of Fast Fourier Transformation (FFT) calculations, both as values and in graphic mode.
Graphs are auto scaled in order to ensure maximum resolution.
The top line provides information on the selected input (U_1, I_1, U_2, I_2, U_3, I_3), its absolute value and the synchronisation frequency.
The bottom line provides details of the selected harmonic component and its absolute and percentage values. The equivalent bargraph is identified by a blinking cursor.

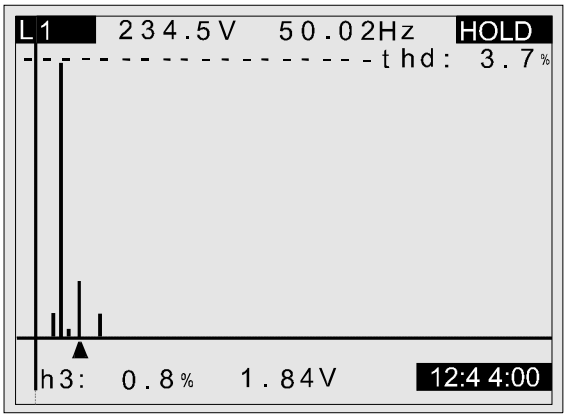


fig. 15: Harmonic Analysis

Use **LEFT** and **RIGHT** keys to select the required bargraph, and the **SELECT** key to choose the required input signal (U_1, I_1, U_2, I_2, U_3, I_3).

7. METER

This function displays the basic measured quantities (AC) in the 3φ system. The display format and legends (V, kV, A, kA, W, kW, MW, etc…) are automatically selected appropriate to the measured values. The following quantities are displayed:

- Phase rms voltage (U_1, U_2, U_3).
- Phase rms current (I_1, I_2, I_3).
- Per phase signed active ,apparent and reactive powers (±P, ±S, ±Q).
- Power Factors with indication of direction (capacitive or inductive).
- Phase angle between voltage and current.
- rms phase to phase voltage (V_{1-2}, V_{2-3}, V_{3-1}).
- Total 3φ signed active, apparent and reactive powers. ($\pm P_t$, $\pm S_t$, $\pm Q_t$)
- Total 3φ Power Factor with indication of direction (capacitive or inductive).
- System frequency.
- Current in neutral conductor, rms value.

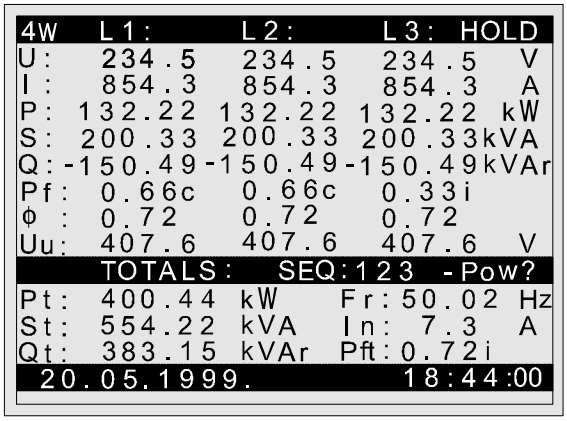


fig. 16: Meter Display Screen

Note: In 3φ systems with a 3wire connection, the Instrument does not display values for the 3rd phase.
The central (TOTALS) line may then display two additional messages:

seq? When three phase system is not connected in the correct phase sequence (L_1-L_2-L_3).

pow? When active power in one or more phase is negative.

Note: Frequency will be displayed in inverse if the instrument is unable to find a valid sync. input. The default sync. frequency (as defined elsewhere) is used.

8. SCOPE (Oscilloscope Function)

This function provides signal waveform displays together with summary details of the signal. The displayed signals are auto-scaled to suit the display, and may vary dependant on the total harmonic distortion.
The top line provides information about the selected input (U_1, I_1, U_2, I_2, U_3, I_3), its value and the synchronisation frequency.

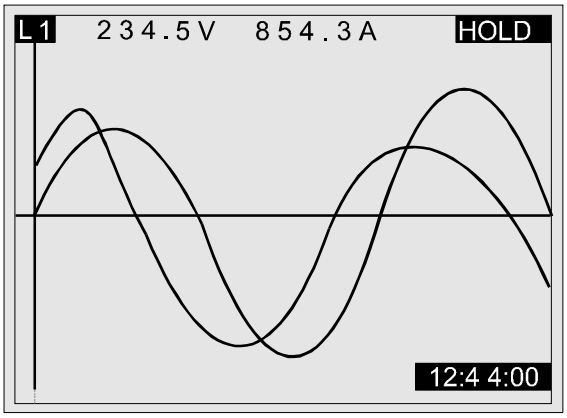


fig. 17: Scope Display without display of additional information

Use the **SELECT** key to toggle between the signal display options (**L_1, L_2, L_3, 3U, 3I, L_1…).**
Display of additional information is controlled by toggling the **ENTER** key.
To scale voltage waveforms: Use **LEFT** or **RIGHT** keys
To scale current waveforms: Use **UP** or **DOWN** keys

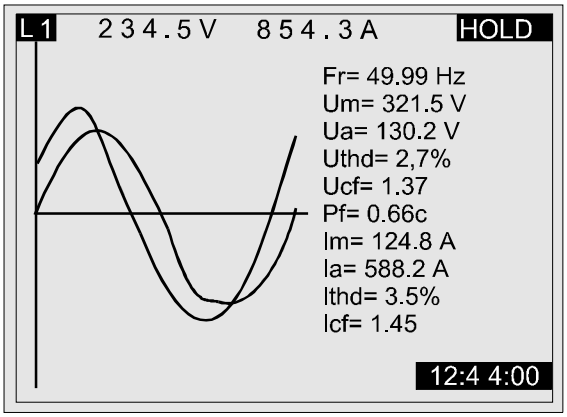


fig. 18: Scope Display with display of additional information

9. Frequency and overload information METER, SCOPE and SPECTRUM screens

The synchronisation frequency is measured on the input selected in the meter configuration menu (L_1, L_2, L_3 or I_1). If no valid frequency can be detected (after software filtering) the Instrument will, if in AUTO mode, scan the other channels for signal that could be used for synchronisation. If no stable frequency signal can be found, the Instrument will use the default (50-60Hz) frequency selected in the METER configuration menu and display this frequency value in inverse.

If an input overload is detected (voltage input > 550V ac or current input >2 V ac), or if there is a peak over-range (770V for voltage inputs and 2.5V for current), this will be indicated on the instrument display by a black arrow pointing to the particular input.

SECTION IV
CONNECTION TO POWER SYSTEMS

Warning
This Instrument requires connection to dangerous voltages

This instrument can be connected to the 3φ system in 3 ways:

- 3φ four wire system L_1, L_2, L_3,N; I_1, I_2, I_3
- 3φ three wires system L_{12}, L_{23}, L_{31}; I_1, I_2, I_3
- Aaron (2 wattmeter) 3φ connection L_{12}, L_{32}, I_1, I_2

The actual connection scheme must be defined in METER Configuration menu (see fig 19 below).

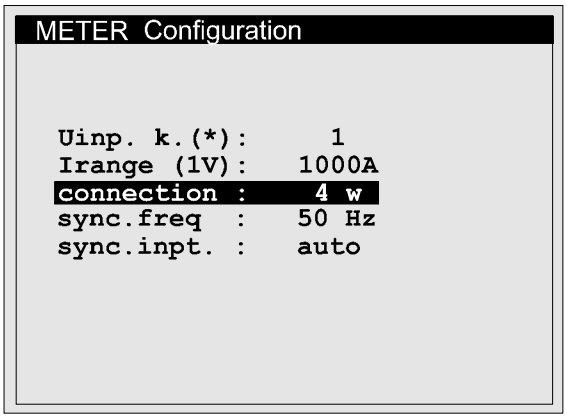


fig. 19: Meter Configuration Menu

Use **LEFT** and **RIGHT** keys to select the appropriate connections scheme.

When connecting the instrument, it is essential that both current and voltage connections are correct. In particular, the following rules must be observed:

- **Current Clamp-on CTs**
  The arrow marked on the Current Clamp-on CTs must point in the direction of current flow, from supply to load.
  If a Clamp-on CT is connected in reverse, the measured power in that phase would normally appear negative.
- **Phase Relationships**
  The Clamp-on CT connected to current input connector I_1 **MUST** be measuring the current in the phase to which the voltage probe from L_1 is connected.

Wiring connections are shown in *fig. 20*, *fig. 21* and *fig. 22* below.

On systems where the voltage is measured on the secondary side of a voltage transformer (say 11 kV / 110 V), a scaling factor taking account of that voltage transformer ratio must be entered in order to ensure correct measurement (see Section III 3.2.5 METER Configuration).

1. 3φ 4 wire system (with Neutral conductor)

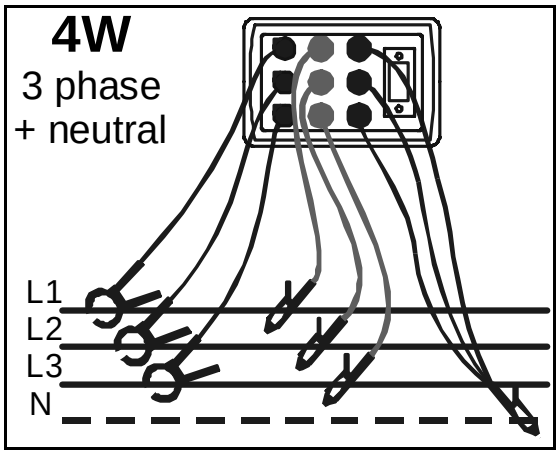


fig. 20: 3φ 4 wire system

2. 3φ 3 wire system with 3 CTs (no Neutral conductor)

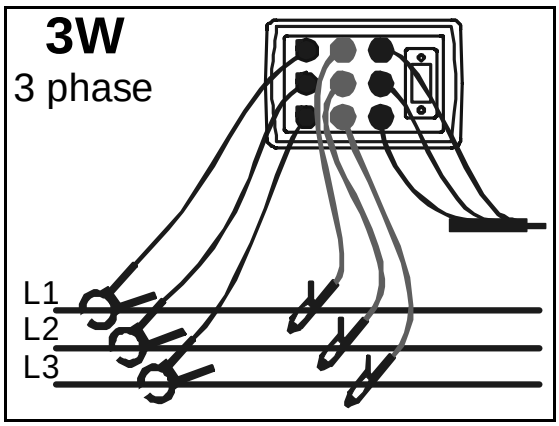


fig. 21: 3φ 3 wire system with 3 CTs

3. 3φ 3 wire system with 2 CTs (2 Wattmeter connection)

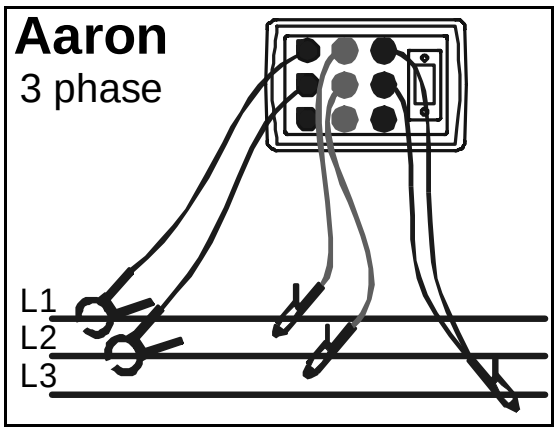


fig. 22: 3φ 3 wire system with 2 CTs (2 Wattmeter connection)

WARNING
Connecting to Current Transformers
The secondary of a current transformer must NOT be open circuited when on a live circuit.
An open circuit secondary can result in a dangerously high voltage across the terminals.

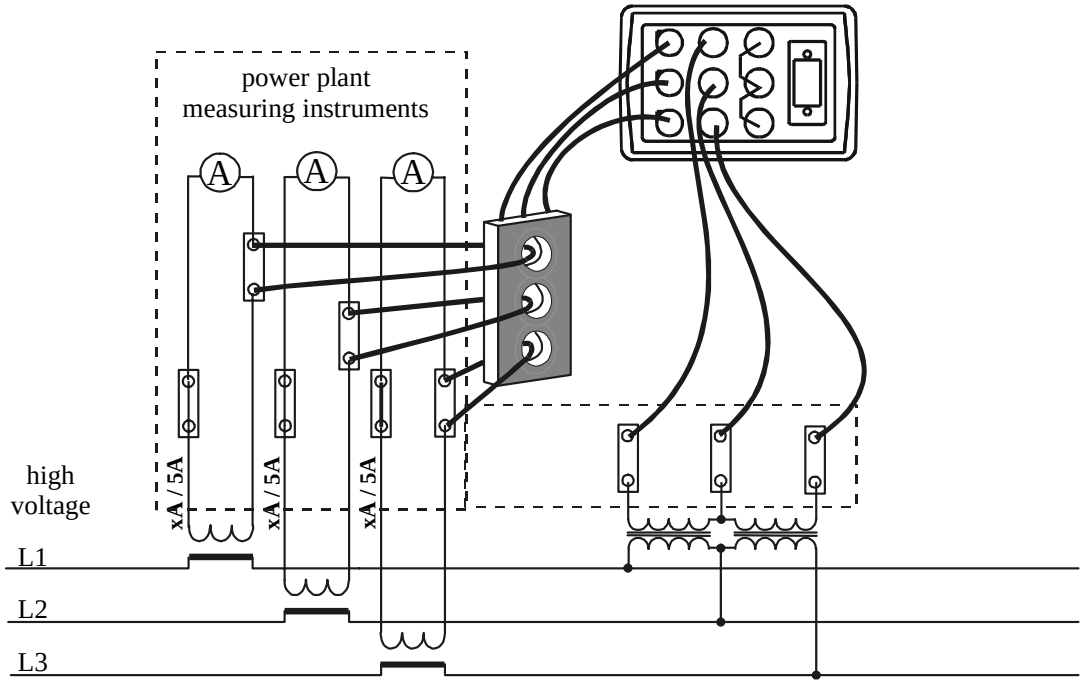


fig. 23: Connecting to existing CTs on a high voltage system

SECTION V
PC software

The Power Harmonic Analyser is supplied complete with a powerful suite of Windows software that can be used for:

- Configuring the Instrument
- Setting measurement parameters
- Download of recorded data
- Off-line analysis of recorded data
- On-line capture and analysis of current voltage and power signals.

The software also provides the necessary tools to allow measured data etc to be included in various reports.

The Minimum requirement for running the software is the ability of the PC to run Windows 3.1.

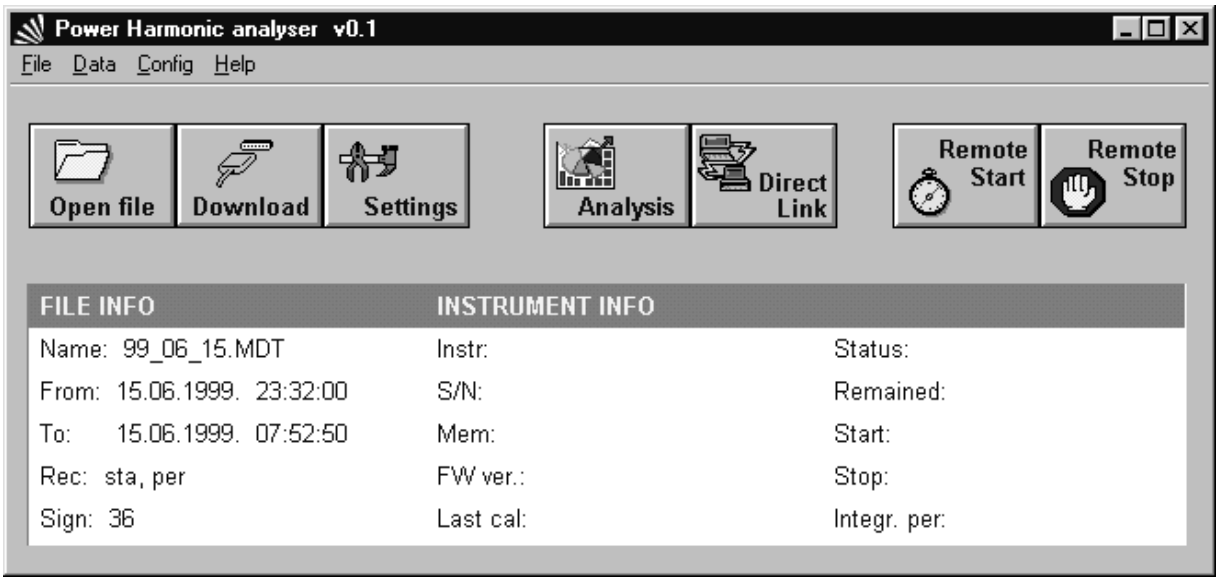


fig. 24: Basic opening screen

The Basic opening screen is the starting point for all actions. It provides general information about the Instrument and - by clicking on 'toolbar buttons' or selecting pull-down menus - access to all functions. The buttons provide access to:

- Download of data
- Setting Instrument configuration parameters
- Analysis of downloaded or previously saved data
- Direct Link - Operating on-line with the Instrument
- Data Logging START/STOP

To set the instrument configuration parameters, double click on **Settings**; the programme will download current settings from the instrument and display them on the screen.

1. INSTRUMENT SET-UP

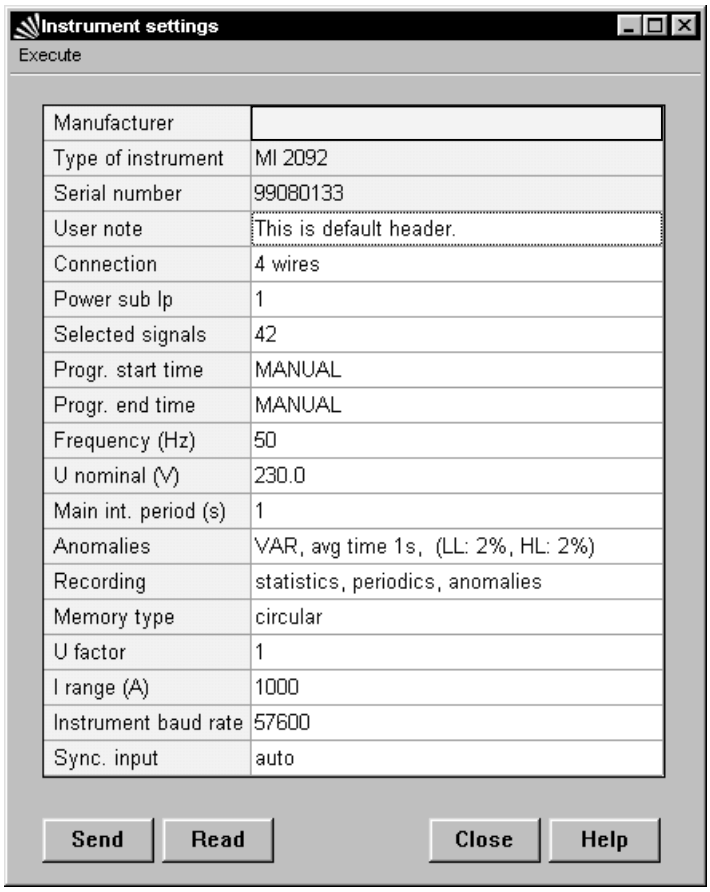


fig. 25: Instrument settings screen

To change default values, double click on the specific field and select between the available options:

User note This field is available for entry of any text: Name, Survey Reference, etc. Text in this field is used just as note of separate data file and is not used for creating final outprints.

Connection Select the System Connection.
(Aaron is a 3 wire measurement with 2 CTs)

fig. 26: Connection screen

Power sub-ip (sub-interval)

Increment / Decrement the value using PgUp / PgDown keys.

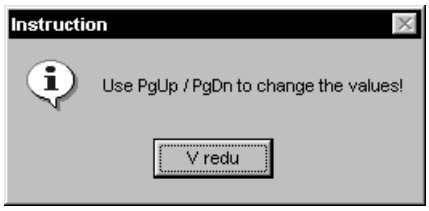


fig. 27: Instruction screen

Selected signals From the list of available signals, select those signals, which you require to be logged, recorded and analysed.
To select a signal, click the left mouse button on the selected parameter.

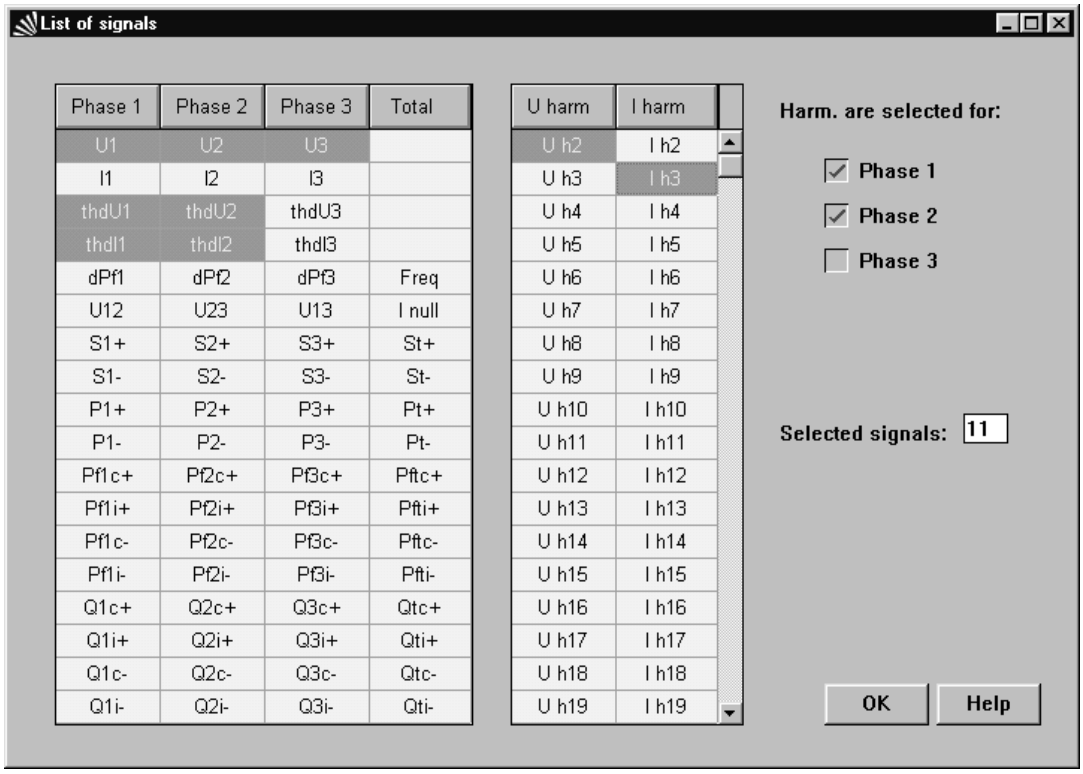


fig. 28: Data Logging Signal Selection screen

Programme start time Programme stop time

Select either Manual or Automatic recording START / STOP.

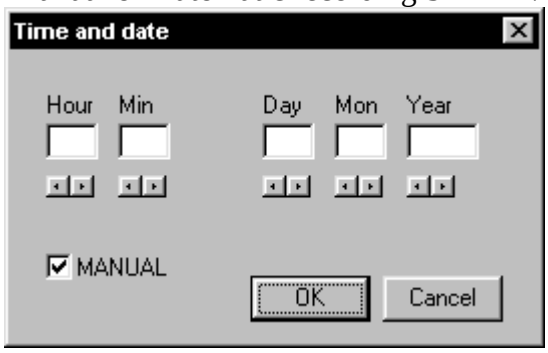


fig. 29: Time & Date Set-up screen

Frequency (Hz) To toggle between 50Hz and 60Hz, double click on the Frequency field.

U nominal (V) (Nominal Voltage)

Increment / Decrement the value using PgUp / PgDown keys.

Main Integration period

Increment / Decrement the Integration Period using PgUp / PgDown keys.

Anomalies settings

Select between Fixed and Variable Nominal Voltage.

Set Lower and Upper limit (with reference to the Nominal Voltage).

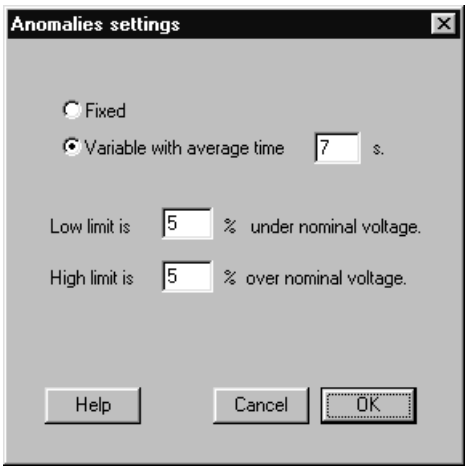


fig. 30: Voltage Anomaly Set-up screen

Recording Select the type of Data Analysis required.

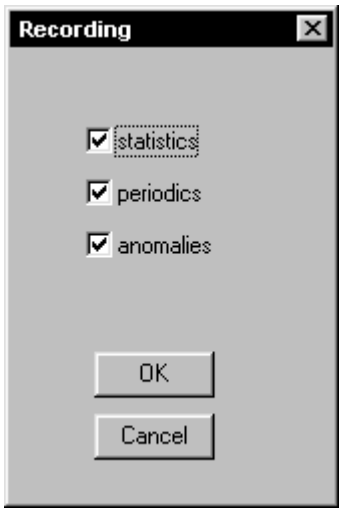


fig. 31: Recording Set-up screen

Memory type Toggle between Circular and Linear memory mode by double clicking on the field.

U factor (Voltage Transformer Ratio)
Increment / Decrement the value using PgUp / PgDown keys.

I range (A) (Scale Factor for the Current Transformers)
Increment / Decrement the value using PgUp / PgDown keys.

Instrument Baud Rate
Increment / Decrement the value using PgUp / PgDown keys.

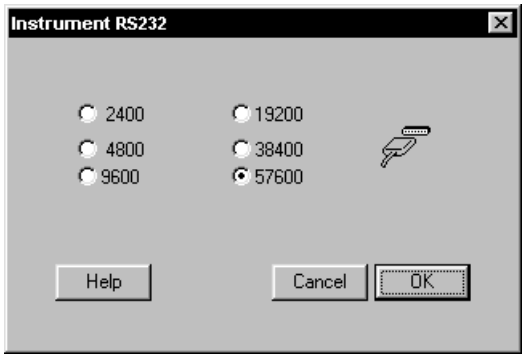


fig. 32: Baud Rate Set-up screen

Sync Input (Frequency Synchronisation Input)
Increment / Decrement the value using PgUp / PgDown keys.

Send Button Click on the **Send** button to update the Instrument settings.

To return to the Main Menu, click on the **Close** button.

2. DATA LOGGING & ANALYSIS

Remote Start button Start Recording.

Remote Stop button Stop Recording.

Download button Download data from instrument to the PC.

Analysis button Analyse Data

The File settings and Analyses menu is displayed:

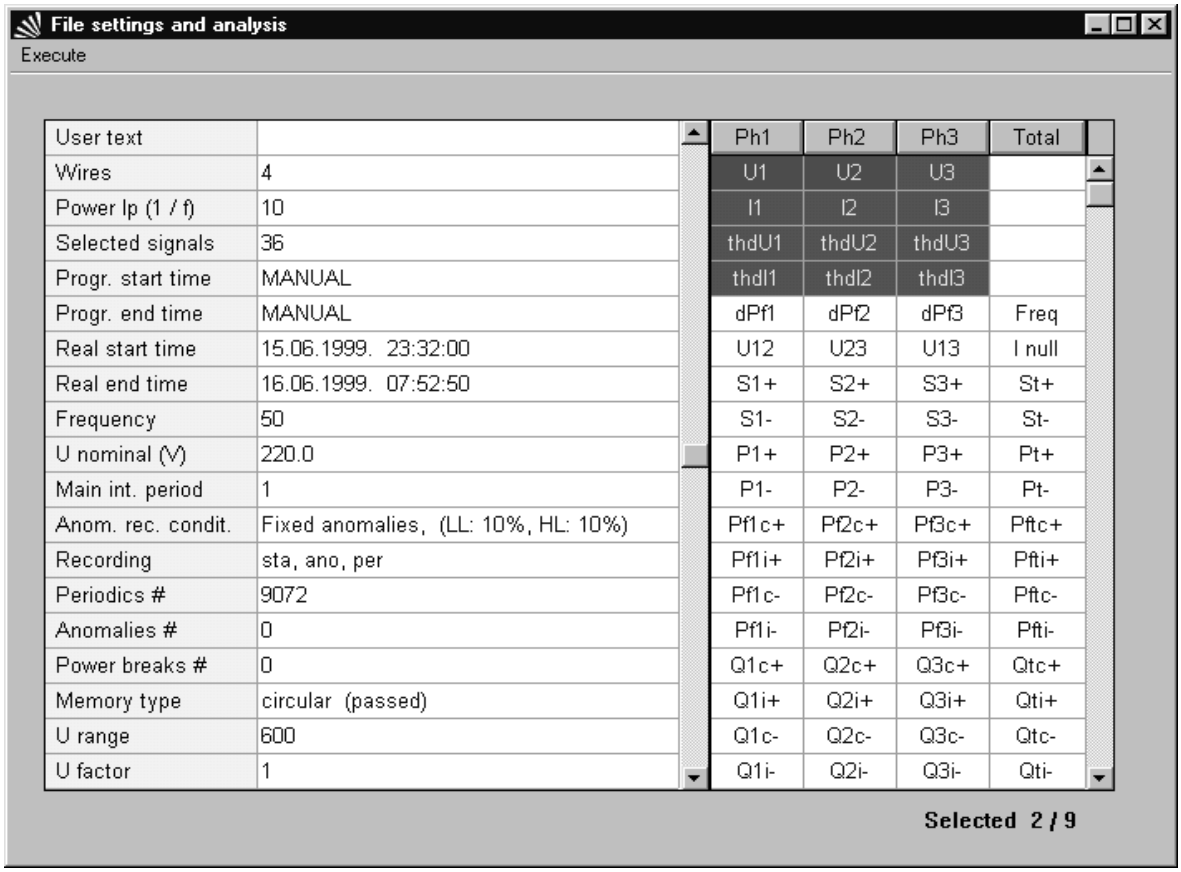


fig. 33: Data Logging Set-up and Status screen

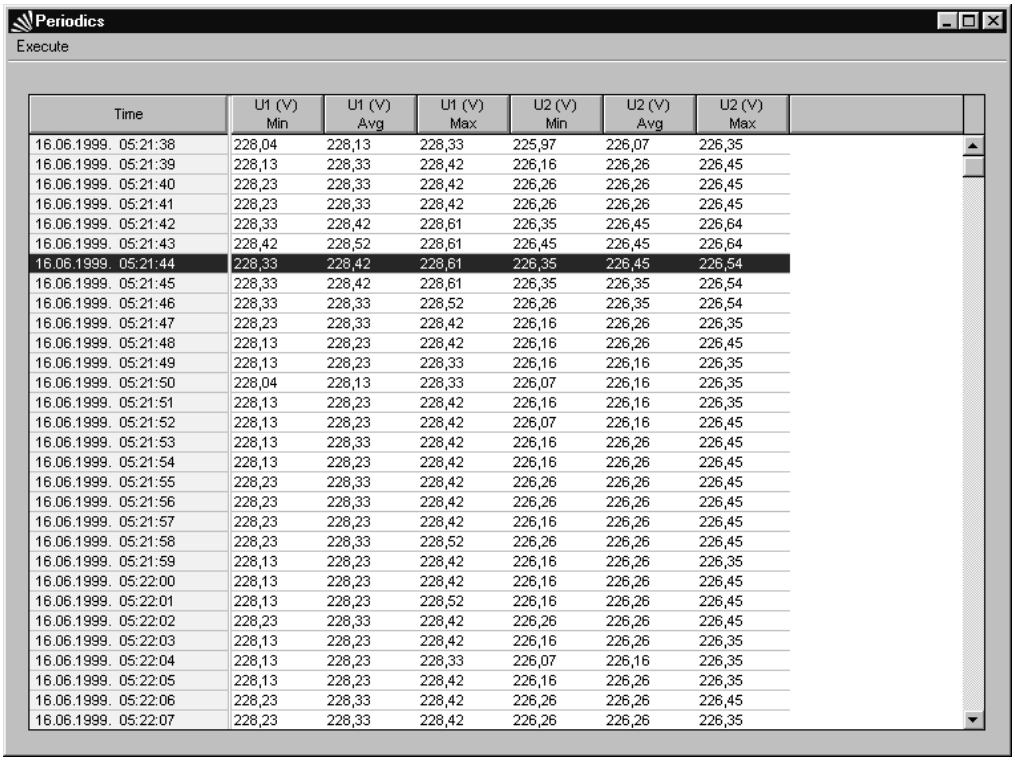
Recorded signals (available for analysis) are coloured blue.
To select a signal for analysis, click on the blue coloured field, which changes to red when selected.
Once parameters have been selected, click on '**Execute**' on the Menu Bar and select the type of analysis required:

- Periodic Analysis
- Voltage Anomalies
- Statistical Analysis

In the following examples, U_1 and U_2 have been selected for analysis; the Integration Period is set to 1 minute.

Periodic Analysis

Recorded data can be analysed in numerical form.



Time	U1 (V) Min	U1 (V) Avg	U1 (V) Max	U2 (V) Min	U2 (V) Avg	U2 (V) Max
16.06.1999. 05:21:38	228,04	228,13	228,33	225,97	226,07	226,35
16.06.1999. 05:21:39	228,13	228,33	228,42	226,16	226,26	226,45
16.06.1999. 05:21:40	228,23	228,33	228,42	226,26	226,26	226,45
16.06.1999. 05:21:41	228,23	228,33	228,42	226,26	226,26	226,45
16.06.1999. 05:21:42	228,33	228,42	228,61	226,35	226,45	226,64
16.06.1999. 05:21:43	228,42	228,52	228,61	226,45	226,45	226,64
16.06.1999. 05:21:44	228,33	228,42	228,61	226,35	226,45	226,54
16.06.1999. 05:21:45	228,33	228,42	228,61	226,35	226,35	226,54
16.06.1999. 05:21:46	228,33	228,33	228,52	226,26	226,35	226,54
16.06.1999. 05:21:47	228,23	228,33	228,42	226,16	226,26	226,35
16.06.1999. 05:21:48	228,13	228,23	228,42	226,16	226,26	226,45
16.06.1999. 05:21:49	228,13	228,23	228,33	226,16	226,16	226,35
16.06.1999. 05:21:50	228,04	228,13	228,33	226,07	226,16	226,35
16.06.1999. 05:21:51	228,13	228,23	228,42	226,16	226,16	226,35
16.06.1999. 05:21:52	228,13	228,23	228,42	226,07	226,16	226,45
16.06.1999. 05:21:53	228,13	228,33	228,42	226,16	226,26	226,45
16.06.1999. 05:21:54	228,13	228,23	228,42	226,16	226,26	226,45
16.06.1999. 05:21:55	228,23	228,33	228,42	226,26	226,26	226,45
16.06.1999. 05:21:56	228,23	228,33	228,42	226,26	226,26	226,45
16.06.1999. 05:21:57	228,23	228,23	228,42	226,16	226,26	226,45
16.06.1999. 05:21:58	228,23	228,33	228,52	226,26	226,26	226,45
16.06.1999. 05:21:59	228,13	228,23	228,42	226,16	226,26	226,35
16.06.1999. 05:22:00	228,13	228,23	228,42	226,16	226,26	226,45
16.06.1999. 05:22:01	228,13	228,23	228,52	226,16	226,26	226,45
16.06.1999. 05:22:02	228,23	228,33	228,42	226,26	226,26	226,45
16.06.1999. 05:22:03	228,13	228,23	228,42	226,16	226,26	226,35
16.06.1999. 05:22:04	228,13	228,23	228,33	226,07	226,16	226,35
16.06.1999. 05:22:05	228,13	228,23	228,42	226,16	226,26	226,35
16.06.1999. 05:22:06	228,23	228,33	228,42	226,26	226,26	226,45
16.06.1999. 05:22:07	228,23	228,33	228,42	226,26	226,26	226,35

fig. 34: Tabular Data Analysis screen

Data can also be graphed, with advanced navigating and search facilities.

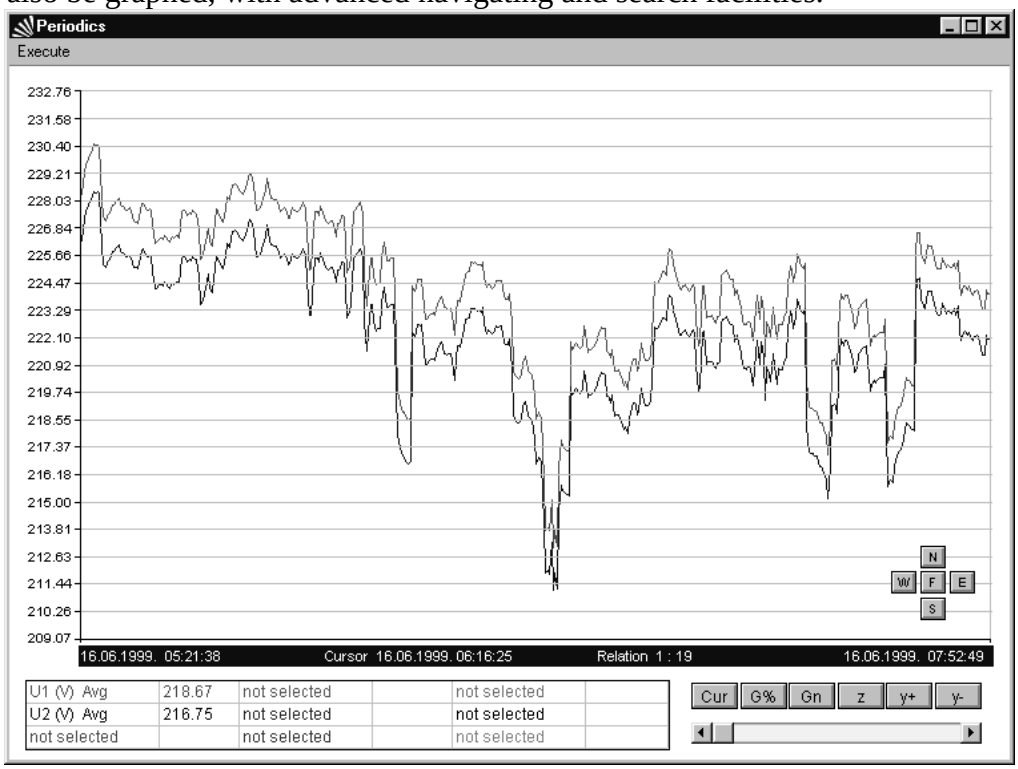


fig.35: Graphic Data Analysis screen

Voltage Anomalies

Recordings of Voltage Anomalies (or Voltage Breaks) can be displayed in both numerical and graphic format.

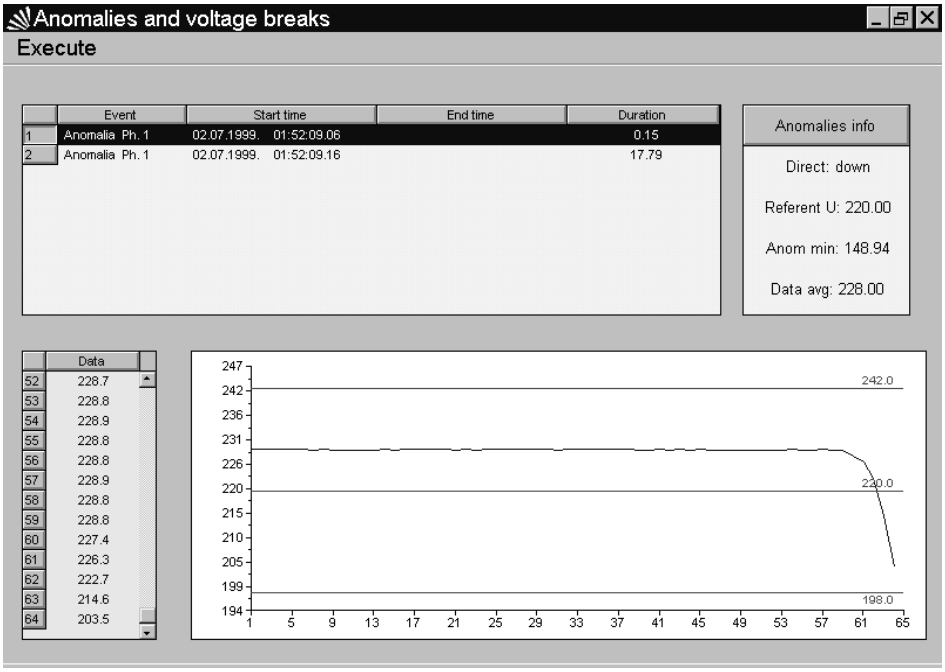


fig. 36: Voltage Anomalies and Breaks screen

A full listing of all Voltage Anomalies is provided, together with the set-up information, and an analysis of each record can be quickly viewed in both graphic and tabular form.

Statistical Analysis

A Statistical Analysis of recorded data can be displayed in both numerical and graphic format.

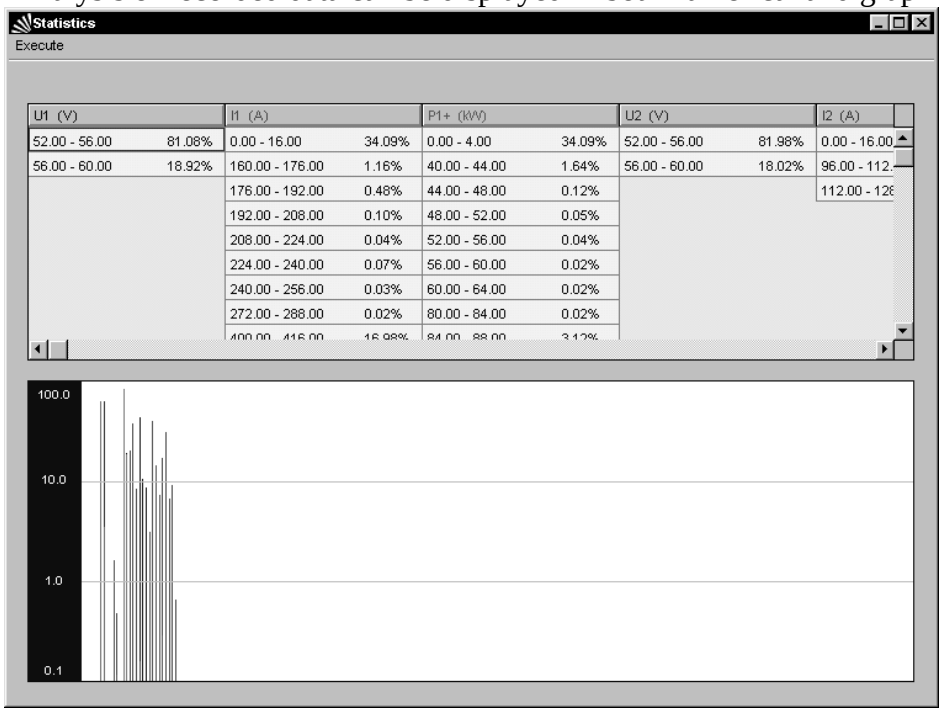


fig. 37: Statistical Analysis screen

3. DIRECT LINK

The Direct Link facility allows direct on-line operation, with real-time values from the voltage and current inputs displayed on the screen. Complex calculation can be carried out and selected input signals waveforms can be saved, can be exported to an ASCII file or to the Clipboard for use with third party analysis tools.
To open the connection to the instrument, click on the '**go!'** button.

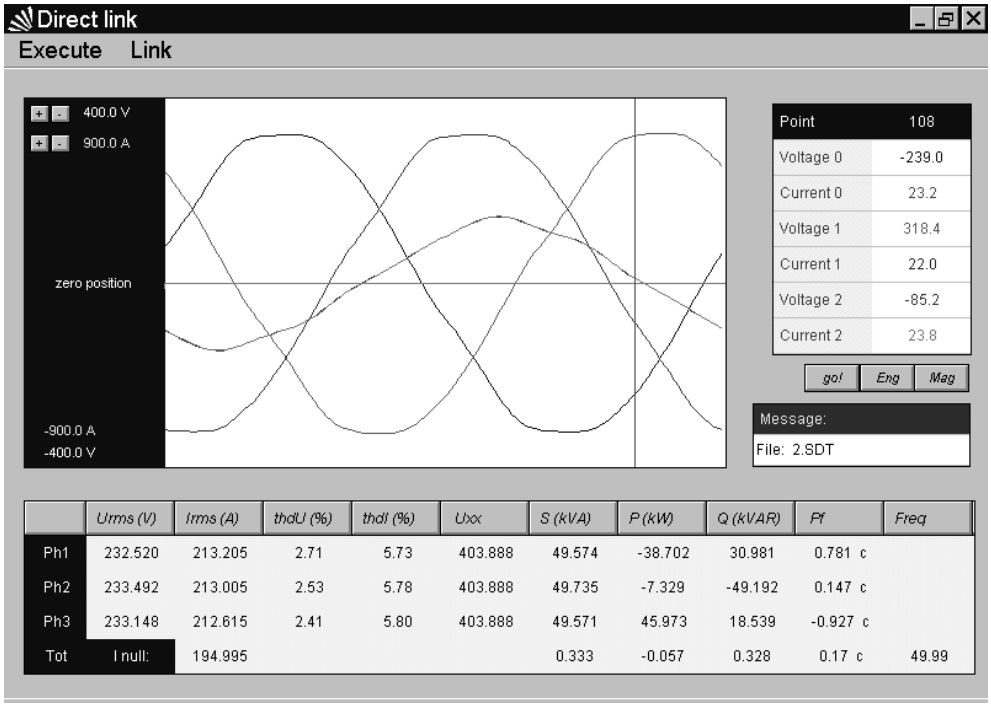


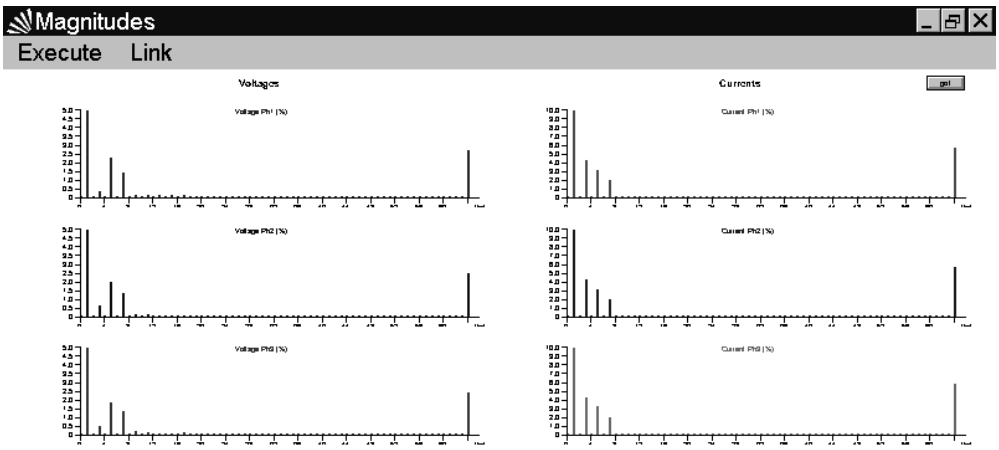
fig. 38: Direct Link oscilloscope screen

To read **Energies** from the instrument, click on the '**Eng**' button. A small window showing the current values of the energies is displayed.

To look at Harmonics, both Voltage & Current, click on the '**Mag**' button. The harmonic analysis screen is displayed, with six histograms – three voltage and three current – showing harmonics up to the 63rd.
To zoom in any histogram, click on **Execute** and **Show Table**. Click on separate histogram to enlarge it.
To alter the scaling of any of the graphs, click on the vertical axis:

Near the top to increase the range.
Near the bottom to expand the scale.

To also show the harmonics in tabular form, select '**Show Table**' from the '**Execute**' menu.
Moving the mouse pointer along any of the graphs will activate a curser, which identifies a single harmonic, with the tabular display scrolling in sympathy with the curser position.
To return to the main **Direct Link** screen, select '**Close**' from the '**Execute**' menu.



Point	U1 (%)	U1 (V)	I1 (%)	I1 (A)	U2 (%)	U2 (V)	I2 (%)	I2 (A)	U3 (%)	U3 (V)	I3 (%)	I3 (A)
0	0.03	0.07	0.14	0.31	0.00	0.00	0.08	0.17	0.07	0.17	0.00	0.00
1	100.00	232.43	100.00	212.86	100.00	233.42	100.00	212.65	100.00	233.08	100.00	212.2
2	0.08	0.18	0.22	0.47	0.10	0.22	0.19	0.40	0.06	0.15	0.22	0.46
3	0.40	0.92	4.28	9.12	0.69	1.60	4.33	9.20	0.54	1.26	4.34	9.22
4	0.06	0.13	0.15	0.31	0.05	0.12	0.19	0.39	0.08	0.18	0.16	0.34
5	2.25	5.24	3.21	6.83	2.00	4.68	3.22	6.84	1.89	4.40	3.24	6.87
6	0.02	0.03	0.01	0.03	0.02	0.04	0.02	0.05	0.01	0.02	0.03	0.07
7	1.41	3.27	2.02	4.29	1.35	3.15	2.03	4.32	1.35	3.15	2.03	4.31
8	0.03	0.07	0.02	0.04	0.01	0.03	0.02	0.03	0.02	0.05	0.04	0.08

fig. 39: Direct Link Harmonic Analysis Screen with tabular display

NOTE: If the display appears to become frozen, there is insufficient time for the display to process all the acquired data.
The 'Request Time' (in the 'Execute' menu) should be increased.
For a Baud rate of 57600, a Request Time at least 1300ms is recommended.

SECTION VI
Theory of operation

1. GENERAL

Data recording is one of the main functions of the instrument. However, while recording data for later analysis, the Instrument can also carry out the following functions:.

- **Statistical analysis – Statistical analysis of the measured signals.**
- **Periodic analysis – On line recording and analysis of various measured signals over preset periods.**
- **Voltage anomalies - Detection and recording of voltage anomalies.**
- **Power breaks – Detection and recording of supply interruptions.**

Apart from power break recording, which is always enabled, all the other functions are independent and can be disabled or enabled by the user. The measuring principles are the same in all recording functions and are described in Section II-2 below. Averaging and statistical techniques are described later in this section.

Data is stored in non-volatile memory and can be download to a PC for further analysis and printing. Downloading can be carried out either on-line while recording and / or after recording has finished. Independent of the recording status, the Instrument can send all samples of an input signal to a PC (for external analysis and viewing) every second.

2. STATISTICAL ANALYSIS

The input range (from 0 to full scale) for each value is divided in 256 divisions (100 for PF and cosφ). Measured values are scaled accordingly. The result is a statistical table, a Gaussian function, that can be analysed using the PC software (see section V below). Statistical analysis is carried out only on signals selected in the Signals submenu. Statistical analysis cannot be applied to Harmonic measurements.

3. PERIODIC ANALYSIS

Periodic Analysis is carried out over a programmable integration period (IP). This can be set (from 1 second to 30 minutes) by the user. During the integration period, the instrument calculates maximum, minimum and average values of selected quantities. At the end of the Period, these values are stored in memory together with the Period Start date/time and synchronization input.

Stored values differ for the various parameters:

- For THD measurement — Only maximum and average values.
- For voltage harmonics and voltage-current angle — Only maximum and minimum values.
- For current harmonics — Only maximum values.
- All other Parameters — Minimum, maximum and average

Active power is divided in two quantities: Import (positive) and Export (negative).
Reactive power and power factor are divided in four quantities: positive inductive (+i), positive capacitive (+c), negative inductive (-i) and negative capacitive (-c).
Neutral conductor current (I_0) is ignored when measuring in 3 wire connection.
For power, voltage and current measurements, values are stored for each input cycle.
Harmonics and THD values are computed on samples of each 8^{th} input cycle.
For calculation of Average Voltage, voltages less then 2% of full scale ($0.02 \times U_n$) are treated as voltage interruptions and are excluded from any calculations.

The stored maximum and minimum values are based on values calculated during each input cycle, while average values (except for voltage, power & harmonics) are calculated at the end of each IP and are based on the number of input cycles in the period.
Average values for power, voltage and harmonic components ignore input cycles where the voltage is lower then $0.02 \times U_n$. Further, if a Power Break or a Power Up occurs during an IP or the IP starts during a Power Break, the Instrument will start a new cycle (see also Power Break recording below).
The following figures and table offer a detailed descriptions of the values used for recording.
The meaning of abbreviations is described below.

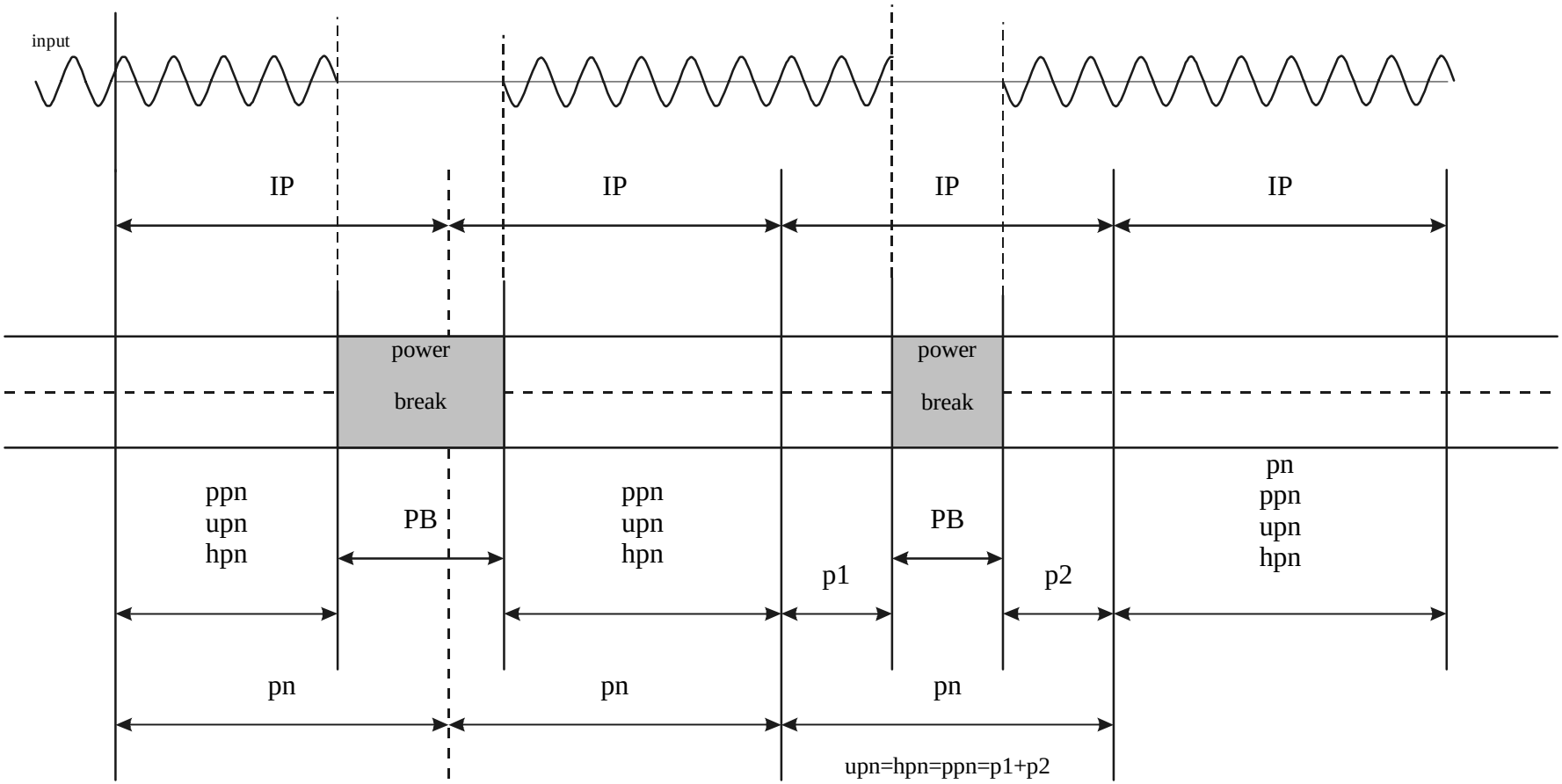
SYMBOL DEFINITIONS

General symbols

U	rms voltages
I	rms currents
P	active power
S	apparent power
Q	reactive power
I_0	rms neutral conductor current
PF	power factor
Cosφ	voltage - current phase angle
THD	total harmonic distortion
H	individual harmonics (%)
h	individual harmonic (V or A)
IP	integration period

Additional symbols

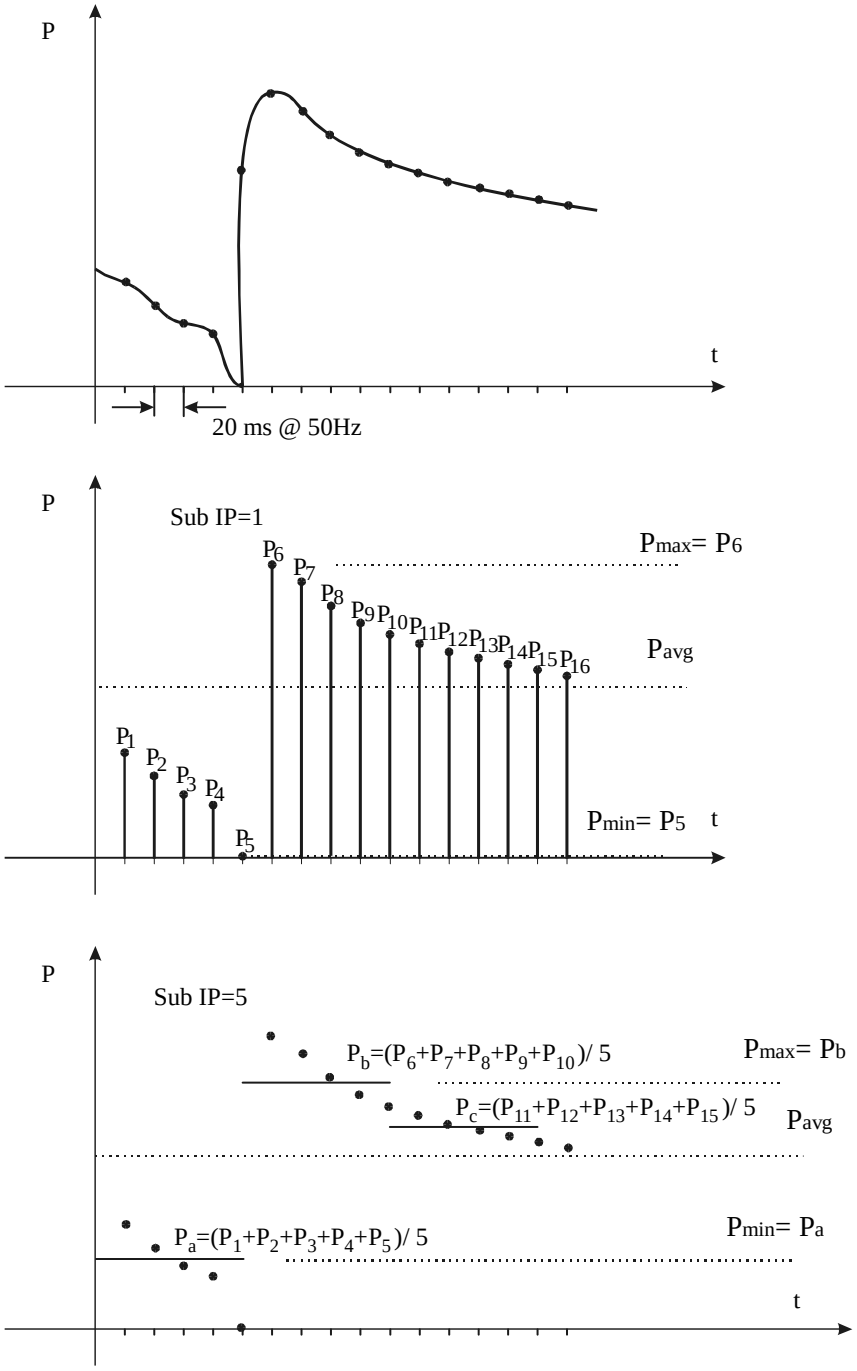
x	phase
t	total
i	inductive (with P, Q or PF symbol)
c	capacitive (with P, Q or PF symbol)
+	positive (with P, Q or PF symbol)
-	negative (with P, Q or PF symbol)
n	harmonic number (with H or h symbol)
a	average (with any general symbol)
m	max. or min (with any general symbol)
na	not available
pn	N° of input cycles in integration period (IP)
hpn	N° of input cycles for harmonics in IP (pn/8)
ppn	N° of input cycles for powers
upn	N° of input cycles for voltages
PC	personal computer
cr	crest factor
pb	power break time inside IP



Input Cycles used for calculation under various Power Break situations

fig. 40

When measuring Power and Power Factor, values can be calculated for each individual cycle or averaged over a period (the 'Power sub IP') which can be set at any value between 1 and 20 cycles (a 400 ms window at 50Hz).
If the Instrument is recording a power, it automatically calculates and records the energy of the selected power in an IP.
Values used for the calculation of maximum and minimum Powers and Power Factors are the average values calculated on power sub IP values (see *fig. 35* below)**.**
Recording of voltage or current THD is automatically enabled if one or more individual voltage or current harmonics are selected.



Examples of calculation of Maximum & Minimum values for various 'Power sub IP' periods

fig. 41

Minimum & Maximum PER PHASE Values

	LOAD TYPE				
VALUE	**POSITIVE**		**NEGATIVE**		**Note**
	inductive	capacitive	inductive	capacitive	[formula]
m P_{X+}	P_X		0		[3]
m P_{X-}	0		P_X		[3]
m Q_{Xi+}	Q_X	0	0	0	[7]
m Q_{Xc-}	0	Q_X	0	0	[7]
m Q_{Xi-}	0	0	Q_X	0	[7]
m Q_{Xc+}	0	0	0	Q_X	[7]
m PF_{Xi+}	PF_X	1	na	na	[8]
m PF_{Xc+}	1	PF_X	na	na	[8]
m PF_{Xi-}	na	na	PF_X	1	[8]
m PF_{Xc-}	na	na	1	PF_X	[8]
m U_X	U_X				[1]
m I_X	I_X				[2]
m $U_X$thd	$U_X$thd				[10] -max only
m $I_X$thd	$I_X$thd				[11] -max only
m $\cos\varphi_X$	$\cos\varphi_X$				[9]
m U_XH_n	U_XH_n				[12]
m I_XH_n	I_XH_n				[13] -max only

Available Maximum & Minimum per phase Values for each Input Cycle

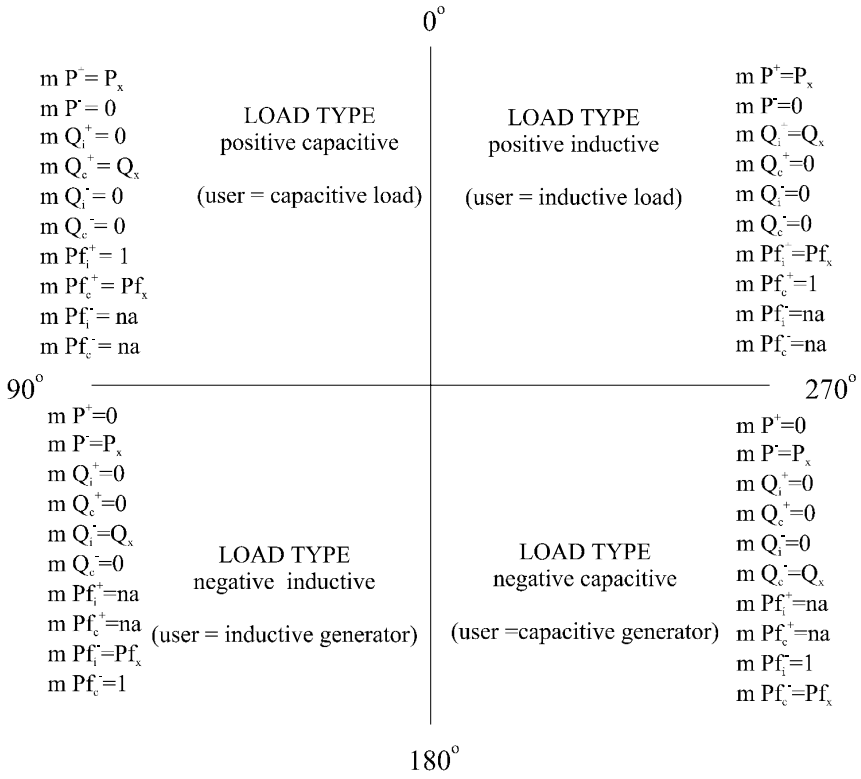
Note: *$U_X$thd, $I_X$thd, $\cos\varphi_X$, U_XH_n, I_XH_n are calculated every 8^{th} input cycle*

Minimum & Maximum TOTAL (3φ) Values

	LOAD TYPE				
VALUE	**POSITIVE**		**NEGATIVE**		**Note**
	inductive	capacitive	inductive	capacitive	[formula]
m P_{t+}	P_t		0		[14]
m P_{t-}	0		P_t		[14]
m S_{t+}	S_t		0		[16]
m S_{t-}	0		S_t		[16]
m Q_{ti+}	Q_t	0	0	0	[15]
m Q_{tc-}	0	Q_t	0	0	[15]
m Q_{ti-}	0	0	Q_t	0	[15]
m Q_{tc+}	0	0	0	Q_t	[15]
m PF_{ti+}	PF_t	1	na	na	[17]
m PF_{tc-}	1	PF_t	na	na	[17]
m PF_{ti-}	Na	na	PF_t	1	[17]
m PF_{tc}	Na	na	1	PF_t	[17]
m I_0	I_0				
m Freq	Freq				

Available Maximum & Minimum 3φValues for each Input Cycle

Note: *P_t, S_t and Q_t are average values in power sub integration period which is from 1 to 20 input cycles. PF_t is also a result of those values*



Import/Export and Inductive/Capacitive Phase/Polarity Diagram

fig. 42

Per Phase Values (averaged at the end of an IP)

Watts

$$aP_x^+ = \frac{\sum_{j=1}^{n}\left(P_x^+\right)_j}{pn} \qquad aP_x^- = \frac{\sum_{j=1}^{n}\left(P_x^-\right)_j}{pn}$$

VA

$$aQ_{xi}^+ = \frac{\sum_{j=1}^{n}\left(Q_{xi}^+\right)_j}{pn} \qquad aQ_{xc}^+ = \frac{\sum_{j=1}^{n}\left(Q_{xc}^+\right)_j}{pn}$$

VA

$$aQ_{xi}^- = \frac{\sum_{j=1}^{n}\left(Q_{xi}^-\right)_j}{pn} \qquad aQ_{xc}^- = \frac{\sum_{j=1}^{n}\left(Q_{xc}^-\right)_j}{pn}$$

PF

$$aPf_{xi}^+ = \frac{aP_x^+}{\sqrt{\left(aQ_{xi}^+\right)^2 + \left(aP_x^+\right)^2}} \qquad aPf_{xc}^+ = \frac{aP_x^+}{\sqrt{\left(aQ_{xc}^+\right)^2 + \left(aP_x^+\right)^2}}$$

PF

$$aPf_{xi}^- = \frac{aP_x^-}{\sqrt{\left(aQ_{xi}^-\right)^2 + \left(aP_x^-\right)^2}} \qquad aPf_{xc}^- = \frac{aP_x^-}{\sqrt{\left(aQ_{xc}^-\right)^2 + \left(aP_x^-\right)^2}}$$

Volts & Amps

$$aU_x = \frac{\sum_{j=1}^{n}\left(U_x\right)_j}{upn} \qquad aI_x = \frac{\sum_{j=1}^{n}\left(I_x\right)_j}{pn}$$

Harmonics

$$aU_x thd = \frac{\sqrt{H_y U_x}}{H_1 U_x} * 100 \;;\quad H_y U_x = \frac{\sum_{z=1}^{n}\left(\sqrt{\sum_{j=2}^{63}\left(Uh_n\right)_j^2}\right)_z}{hpn} \;;\quad H_1 U_x = \frac{\sum_{z=1}^{n} U_x h_1}{hpn}$$

$$aI_x thd = na \qquad a\cos\varphi_x = na$$

$$aU_x H_n = na \qquad aI_x H_n = na$$

***Note*:** *If power breaks occur, periods 'pn' (for power calculations) and 'upn' (for voltage calculations) are modified to:*

$$pn = \frac{IP}{ic} - \frac{pb}{ic} \qquad upn = \frac{IP}{ic} - \frac{pb}{ic} - ic_l$$

Where: ic = input cycle time
pb = power break time inside the IP
ic_l = number of cycles with $U_X < 0.02\ U_{range}$

Total 3φ Values (averaged at the end of an IP)

Watts	$aP_t^+ = \frac{\sum_{j=1}^{n}\left(P_t^+\right)_j}{pn}$	$aP_t^- = \frac{\sum_{j=1}^{n}\left(P_t^-\right)_j}{pn}$
var	$aQ_{ti}^+ = \frac{\sum_{j=1}^{n}\left(Q_{ti}^+\right)_j}{pn}$	$aQ_{tc}^+ = \frac{\sum_{j=1}^{n}\left(Q_{tc}^+\right)_j}{pn}$
var	$aQ_{ti}^- = \frac{\sum_{j=1}^{n}\left(Q_{ti}^-\right)_j}{pn}$	$aQ_{tc}^- = \frac{\sum_{j=1}^{n}\left(Q_{tc}^-\right)_j}{pn}$
VA	$aS_t^+ = \sqrt{\left(aP_t^+\right)^2 + \left(aQ_{ti}^+ + aQ_{tc}^+\right)^2}$	$aS_t^- = \sqrt{\left(aP_t^-\right)^2 + \left(aQ_{ti}^- + aQ_{tc}^-\right)^2}$
PF	$aPf_{ti}^+ = \frac{aP_t^+}{\sqrt{\left(aQ_{ti}^+\right)^2 + \left(aP_t^+\right)^2}}$	$aPf_{tc}^+ = \frac{aP_t^+}{\sqrt{\left(aQ_{tc}^+\right)^2 + \left(aP_t^+\right)^2}}$
PF	$aPf_{ti}^- = \frac{aP_t^-}{\sqrt{\left(aQ_{ti}^-\right)^2 + \left(aP_t^-\right)^2}}$	$aPf_{tc}^- = \frac{aP_t^-}{\sqrt{\left(aQ_{tc}^-\right)^2 + \left(aP_t^-\right)^2}}$
Current & Frequency	$aI_0 = \frac{\sum_{j=1}^{n} I_{0j}}{pn}$	$aFreq = \frac{\sum_{j=1}^{n} Freq_j}{pn}$

Note: *If power breaks occur, period 'pn' (for power calculations) is modified to:*

$$pn = \frac{IP}{ic} - \frac{pb}{ic}$$

Where: ic = input cycle time
pb = power break time inside the IP

4. VOLTAGE ANOMALY RECORDING

Voltage anomalies occur when a voltage exceeds preset boundaries. The rms voltages of each half input cycle are used for comparison. For every Voltage Anomaly detected, the Instrument stores:

- Date & time when the anomaly started.
- The nominal voltage.
- Minimum or maximum voltage during the anomaly.
- The previous 64 rms values, calculated on half input cycles (half periods), before the anomaly occurred.

Voltage Anomaly recording is enabled on selected voltage inputs and can be calculated based either on a fixed tolerance window or on a variable tolerance window.

In **Fixed Tolerance Mode**, the nominal voltage is set by user and the high and low limits are set as a percentage of nominal voltage. (fig. 43)

In **Variable Tolerance Mode,** the nominal voltage is calculated and is the average voltage during the previous anomaly integration period (settable between 1 and 900 seconds). The new nominal reference voltage can be up to ± 30% of programmed nominal voltage. High and low limits are set as a percentage of the nominal voltage and can be between ± 1% and ± 30% of the nominal voltage. (fig. 43)

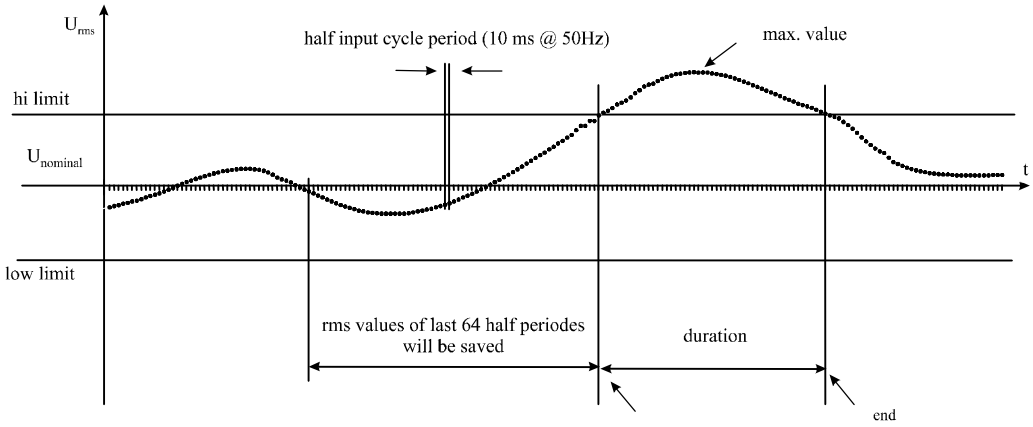


fig 43

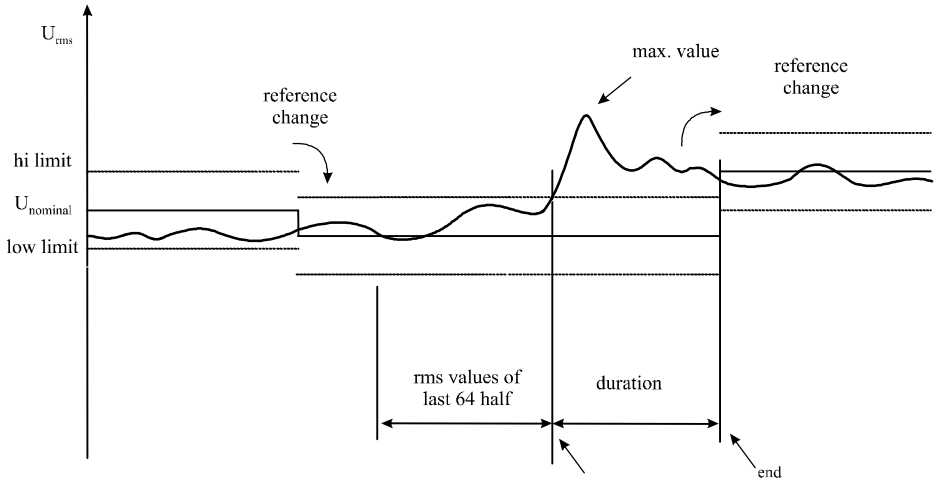


fig 44

5. POWER BREAKS RECORDING

If data logging is in progress, the start of every OFF state of the instrument is treated as a Power Break. This OFF state occurs either if the instrument is switched OFF (using the rotary switch) or if it lose its power supply.
For each Power Break, the instrument logs the date & time of both the beginning and end of the power break, and the cause of the power break (manual or loss of supply).
Note: The battery must be in the instrument, otherwise its power supply drops to fast and it can not record Power Breaks

6. MEMORY USAGE

The non-volatile memory in the Instrument can be used in one of two ways:

- **Linear mode**
  In **linear mode** recording, the Instrument stores data in memory until full and then stops recording. Thus the oldest data is always preserved irrespective of the amount of recordable data.
- **Roll-over mode**
  When recording in **roll-over mode**, the Instrument will over-write old data when memory is filled. Thus, the latest data is always preserved irrespective of the amount of data recorded, with the older data being possibly lost.

Data logging capacity in **linear mode** depends on the number of channels selected for recording, the type of data recorded, the IP and the number of voltages anomalies detected. It is automatically calculated by the PC software when selecting channels for logging and is given by the following equation:

Maximum number of records in Periodic Analysis (***Rn*max**) is given by:

$$Rn_{\max} = \frac{(2032 - N_{Stat}) * 1024 - N_{ano} * 164}{R_{len}}$$

Where:

R_{len}	Record length	$R_{len} = 12 + X * 6 + Y * 12$
N_{stat}	N° of channels selected for Statistical Analysis (All being selected for Periodic Analysis, but excluding harmonics).	
N_{ano}	N° of voltage anomalies which occurred while recording.	
X	N° of channels selected excluding power channels ($\pm P_x$, $\pm Q_x$, $\pm P_{tot}$, $\pm Q_{tot}$, $\pm S_{tot}$).	
Y	Power channels	

Note: Estimating Voltage Anomalies:
N_{ano} can be estimated with experience. It depends on the quality of voltage supply and on the user defined limits for detection of anomalies. Selection of excessively narrow limits, or a wrong nominal voltage reference, can produce large numbers of recorded events and reducing memory capacity.

Example 1:

The Instrument will be set to log for 7 days.
The requirement is to monitor both voltage and current changes, and harmonic distortion, with as much detail as possible.
For optimum memory usage, just 12 channels should be set for periodic analysis.

U_1, U_2, U_3, I_1, I_2, I_3, thd_{U1}, thd_{U2}, thd_{U3}, thd_{I1}, thd_{I2}, thd_{I3}.

With this setting, the Instrument can save 24,771 records (values for 24,771 IPs). Increasing number of channels and/or enabling Statistical Analysis would decrease number of saved IPs.

Rn_{max} = (2032) * 1024 / (12 + 12 * 6) = > 24,771
(Record Length = 12 + 12 * 6 = 84 bytes)

Thus, over a week (604,800 seconds) instrument can save a record every 30 seconds (an IP interval of 30 seconds).

604,800 seconds / 24771 = 24.4 seconds Set IP = 30 seconds

Thus, monitoring the above 12 parameters with an IP of 30 seconds will produce 20,160 records per week in memory. This will leave the following memory free:

FREE Memory = Memory Capacity - Memory Used
2032 * 1024 - 20,160 * 84 bytes
387,328 bytes.

This 'FREE Memory' is enough for recording 2361 Voltage Anomalies. Adding a further channel to the recording (e.g. frequency) would leave the following memory free:

FREE Memory = Memory Capacity - Memory Used
2032*1024 - 20,160 * (84 + 12)
145,408 bytes. (Sufficient for 886 Voltage Anomalies)

Example 2:

The same set-up as above but:
Statistical Analysis is enabled
Phase 1 voltage harmonics (as many as possible) are to be logged.
The Instrument can calculate a Statistical Analysis for all recorded parameters except current and voltage harmonics; thus 12 channels are required for recording statistics.
A maximum of 64 channels can be selected for data logging. The settings for Example 1 above require 12 channels, leaving 48 channels free. The Instrument can record harmonics up to 41st, requiring 40 channels (all possible harmonics from the 2nd to the 41st will be recorded). Thus a total 52 channels need to be set for Periodic Analysis.
The number of records that the Instrument can store with this setting is given by:

Rn_{max} = (2032-12) *1024 / (12 + 52 * 6) = > 6384
(Record Length = 12 + 52 * 6 = 324 bytes)

Thus, if recording is required over one week (604,800 seconds), the shortest recording interval is given by:

Interval = 604,800 seconds / 6384
94.7seconds

Thus setting an IP of 2 minutes will produce 5040 record per week in memory. This will leave the following memory free:

FREE Memory = Memory Capacity - Memory Used
(2032 - 12) * 1024 - 5040 * 324
435,520 bytes.

This would allow recording over a further 44 hours (with no Voltage Anomalies), or for recording 2655 Voltage Anomalies.