USERS MANUAL 2800

SINGLE- TO SIX PHASE

VALHALLA SCIENTIFIC POWER ANALYZER

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1. POWER ANALYZER FEATURES, QUICK OVERVIEW, SAFETY

The Valhalla 2800 High Precision Power Analyzer is available in 1-, 2-, 3-, 4-, 5-, or 6-phase versions. All voltage inputs (ranges 0.3V up to 1500Vpeak) and all current inputs (1.5mA up to 1A; 15mA up to 5A; 1A up to 40A; and current shunt inputs 60mV up to 6V) are potential free and exhibit

- Excellent low noise
- Common mode suppression
- DC-stability
- Wide frequency range (2MHz)
- Very low self-heating on current inputs.

There is no need to fiddle with dc-compensation, or changing current plug-ins. All is built into the input sections of the Power Analyzer, ready to be used.

Your intuition will guide you to operate the Power Analyzer touch screen correctly. With basic knowledge of power measurement you will be able to change the settings to your needs. Almost all setting changes are accomplished with two touches on the display screen or two clicks with the mouse.

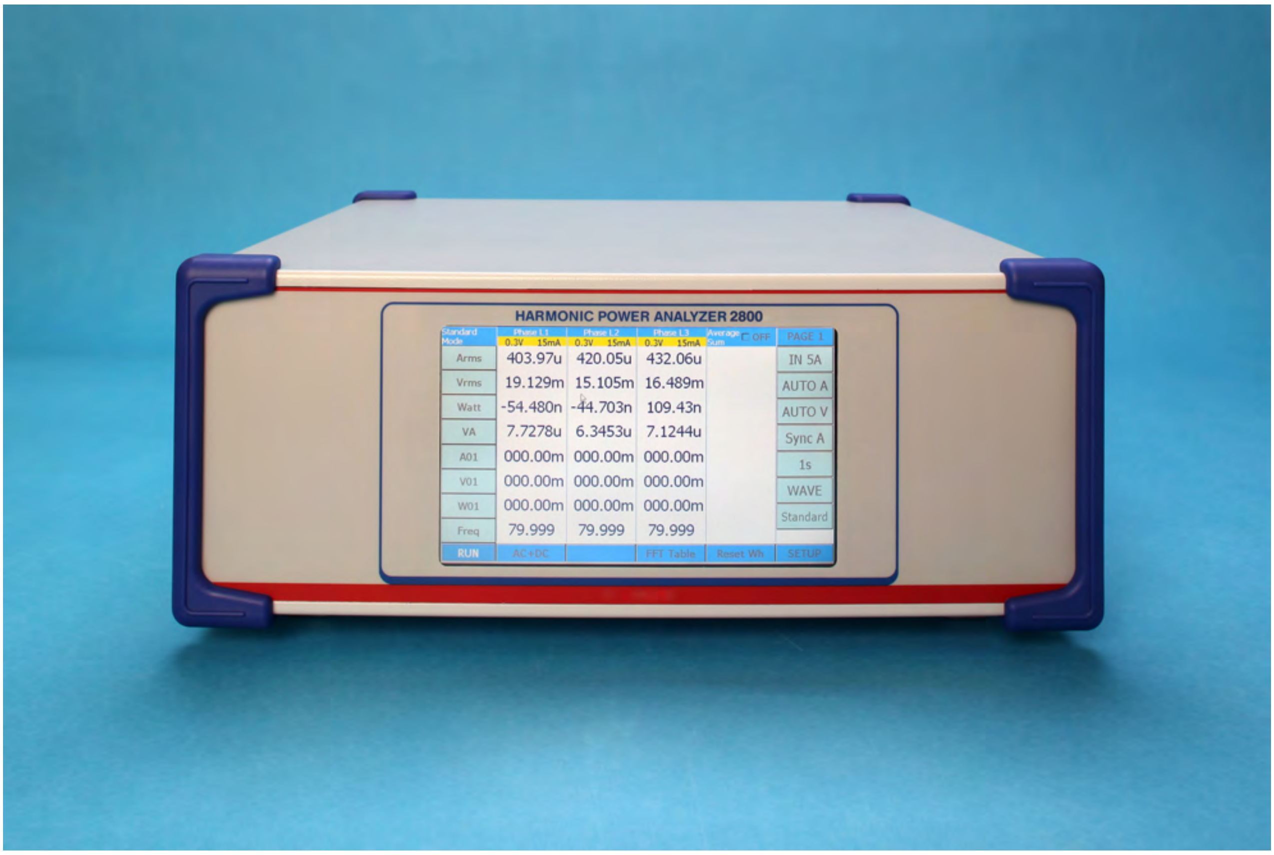


Figure 1.1 Shows the display of a 3-phase instrument in “Standard Mode”.

Figure 1.1 shows the display of a 3-phase instrument in “Standard Mode”. To change the current range from 15mA to 500mA touch the button “AUTOA”. A pop-up window is presented from which you select “500mA”. Now the Power Analyzer is in 500mA current range (manual ranging).

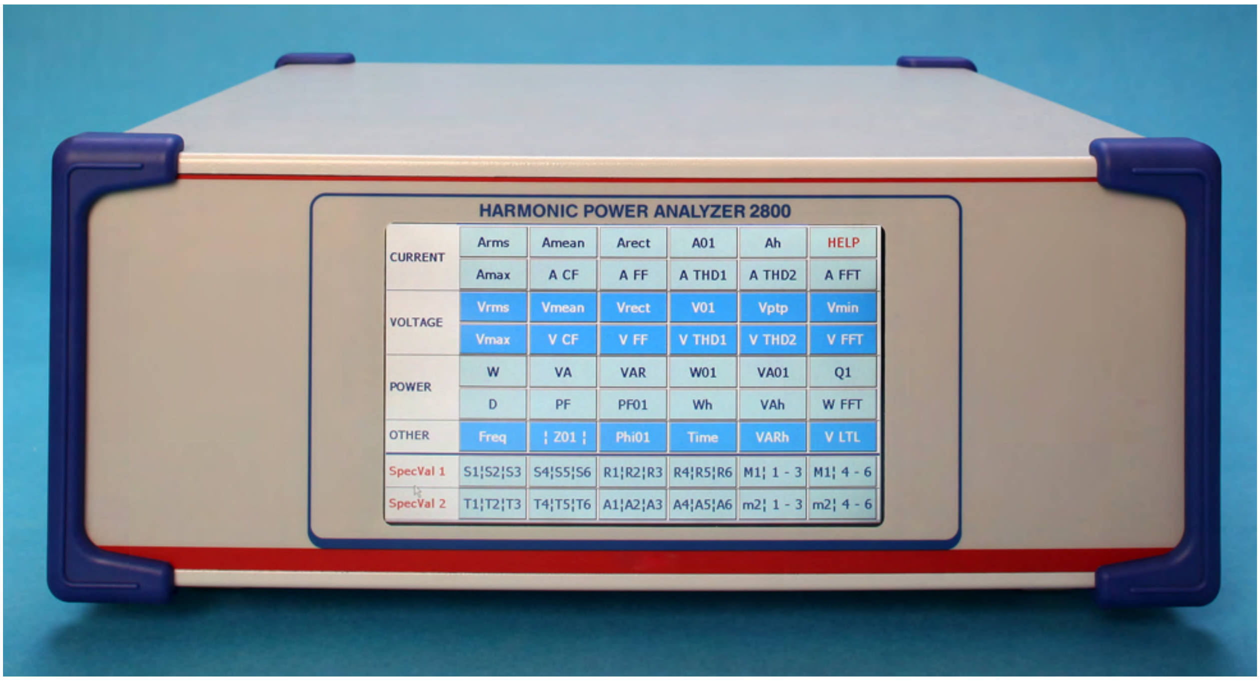


Figure 1.2   2800 Value Selection Table

Just as simple is to change the quantity at the bottom line “Freq” to Arectified mean (Arect). Touch “Freq” at the left side of the display. This will present you a value selection table as shown in Figure 1.2. Now touch “Arect” which brings you back to Figure 1.1 with the bottom line quantity changed to “Arect”.

Four different measure modes enhance the 2800 Power Analyzer capabilities. These are: standard measure mode, logging measure mode, transient measure mode, and power-speed measure mode.

Standard Measure Mode

In the Standard Measure Mode 280 quantities per phase are continuously measured (no gaps) and are updated. Values can be displayed on four display pages, can be saved in internal memory, or can be transferred via Interface to a computer.

Touching “WAVE” will display a sub-menu which lets you select the current-, voltage-, and power wave forms of any phase.

Select “OFF” (Wave OFF). Now you have access to the buttons “FFT Table”. Touching “FFT Table” selects “FFT L1. On five pages you can now view the harmonics of current, voltage, power, and phase angle (harmonics 1 to 40 for current and voltage, harmonic 1-21 for power and phase angle).
Similarly, selecting “FFT Bar” the bar graph of the harmonics will be displayed in percent of the fundamental (1. harmonic).
Touching “FFT L1” will toggle to “FFT L2”, “FFT L3”, and so on.

Logging Measure Mode

The basic operation is as follows: Select the number of cycles for which you desire a periodic data output to the RS232 / USB-interface. If you perform measurements on the 50Hz power line and you select cycles = 1 you obtain new data every 20ms; if you select cycles = 30000 you obtain new data every 10 minutes.

Before starting the measurement a valid synchronization signal 5Hz to 2kHz must be present at the Power Analyzer inputs: select SyncA, SyncV, or S_Ext V. Touch the START-button to start the measurement, touch the STOP-button to stop it. DC signals can also be measured (e.g. DC-motors). For DC you must apply an external synchronization signal in the frequency range 5Hz – 2kHz (select EXT synchronization).
Furthermore, the frequency of the synchronization can be varied up and down as much as 10 % per second.

From every phase you obtain 8 values: frequency, RMS current, RMS voltage, power, power factor, apparent power, energy Wh, and apparent energy VAh.
If you select the baud rate of 463.2 kbaud (in SETUP) a 6-phase Power Analyzer transmits 8 x 6 = 48 values in less than 20ms. This can be used to analyze the start-up behaviour of power systems.

Transient Measure Mode

The transient measure mode can be used in two ways: You can catch current-, voltage-, and power wave forms in a start-up on all phases simultaneously or you can view all wave forms at a critical operating point in Standard Measure Mode. (up to maximum 6 phases).

The duration of the measurement is set by changing in the SETUP menu the Transient-id from 0 to 7. Sections of the wave forms can be expanded by simply touching one of the 4 “Zoom Sectors” (maximum zoom factor is 256).

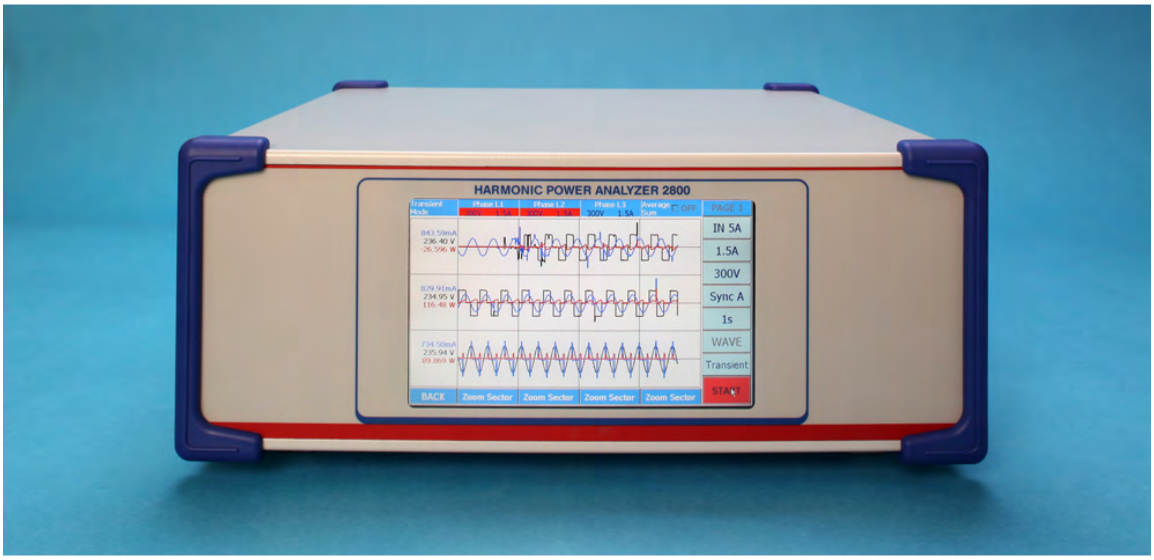


Figure 1.3 2800 3-Phase Power Analyzer Display in Transient Measure Mode

POWER-SPEED MEASURE MODE

This measure mode analyzes the performance of electric devices such as electric cars.

In 20ms intervals the following data are stored in internal memory: RMS current, RMS voltage, power, apparent power, energy, apparent energy, and speed of an axis or a wheel. rms current and –voltage are average values of the number of phases used, power and energy are the sums of phases used.

Power speed measurements can be performed on DC- as well as AC-drives using either phase 1, or phase 1 and phase 2, or using phase 1, 2, and phase 3 of the Power Analyzer.

At end of measurement, (maximum 11 seconds) data versus time are plotted, can be expanded to view details, or can be stored.

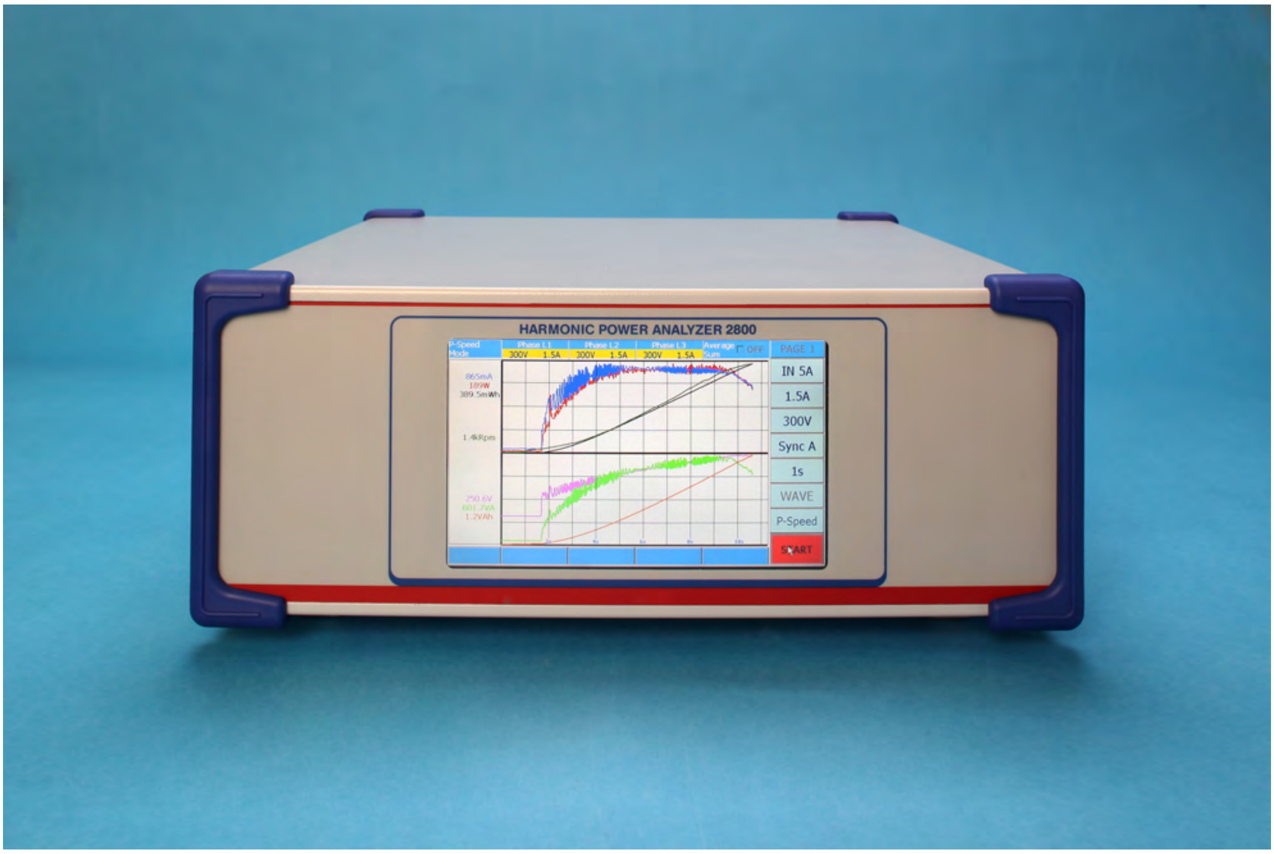


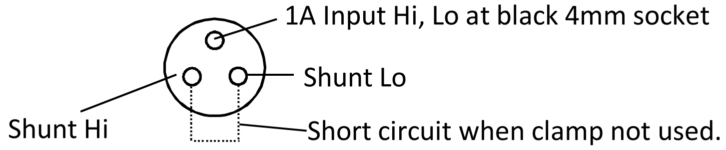
Figure 1.4   2800 3-Phase Power Analyzer in Power-Speed Measure Mode

POWER ANALYZER REAR PANEL

Figure 1.5 shows the 2800 rear panel with three phases installed. Every phase consists of a potential free voltage input along the top side.
Below the voltage inputs are the 40A input, and the 5A input (7A max.) with common Lo socket. Above the 40A socket is the 3 pole Amphenol socket for the 1A input and shunt input. It is normally covered with the shunt short circuit cap.

Figure 1.5 Rear panel of a 3 Phase Power Analyzer

All four current inputs are referenced to the black Lo socket and are potential free.



- Figure 1.6 3 pole Amphenol Socket for 1A current input and shunt input

For use of 1A input remove the shunt short circuit cap and insert the 1A adapter. The 1A adapter is the Hi input, and the black current socket is the 1A Lo.

Caution: When 1A adapter is removed the shunt short circuit cap must be inserted.

SUMMARY OF 2800 POWER ANALYZER FEATURES

- Available as 1-, 2-, 3-, 4-, 5-, or 6-phase instrument.
- Highest precision available: 0.02 % reading + 0.02 % range.
- 18 bit measurement resolution. High accuracy at 10 % full scale.
- Wide angle, touch-screen TFT color display (800 x 480 pixels).
- Simple to operate, most settings in 2 steps (2 touches).
- Standard-, Logging-, Transient-, Power-Speed measurement functions.
- Standard: calculates all quantities of power electronics, including motor- and transformer values, harmonics, energies, analog inputs, and speed.
- Very fast data transfer; up to 3400 values per second.
- High DC precision for solar applications.
- Includes 4 current inputs: 1mA - 1A, 15mA - 5A, 1A - 40A, shunt.
- Voltage Ranges: 0.3V to 1000V.
- Large memory for measurement data and settings (1G Byte Memory)
- USB interface for downloading measurement data
- Ethernet interface
- Optional interfaces: RS232 / USB, IEEE-488
- Optional: 2 frequency inputs max 150kHz, 6 analog inputs, and 12 analog outputs.
- Interface commands for fast data transmission.
- Optional operating software under Windows, LabView Driver
- Reasonably priced by virtue of smart design.
- Simple servicing, modular concept, pre-calibrated input amplifiers.
- Optional high precision, broadband, current sensors.
- Optional 30A coaxial shunt (current viewing resistor).
- Upgrading the number of installed phases is possible at any time

Safety Instructions

The manufacture of this equipment conforms to the safety standards defined in
IEC 61010-1.

Protection: The device assigns to protection class I and is equipped with a protective earth stud.

This equipment may be operated only by qualified personnel. A qualified person has completed training to operate a Power Analyzer.

Proper Use

Do not exceed maximum currents of the 1A-input, 5A-input, 30A-input, and the shunt input
Do not exceed maximum voltages on voltage inputs. Do not exceed 1000V on any input terminal with respect to case.
Improper use or modifying any part of the equipment shall void all warranty

Warranty
The warranty period is 2 years from the date of purchase

Connecting a Power Analyzer

- Use a power line cable with earth connection
- Inspect the connecting cable for faulty connection
- Connect the rear panel earth stud to power ground
- Make cable connections with the help of a second qualified person
- Ensure that connected devices work properly
- In the case of direct connection to current circuits we recommend to use an external protection circuit to not exceed the maximum current input in use (1A, 5A, 30A)
- Refer Power Analyzer servicing and repair to authorized organizations
- Use of this instrument in life support systems and in systems for people transportation must be expressly authorized by the manufacturer

2. CONNECTION TO CIRCUITS

Please read section "Safety" of this manual before preforming the measurements described below.

MEASUREMENT IN 3-PHASE MAINS CIRCUIT

- **THREE WATTMETER CONNECTION**

Power and energy consumed by a load are positive values. This means that current Hi and Lo, and voltage Hi and Lo must be connected in correct directions (polarity).

Rule 1: All currents flow from supply to load that is into the red current socket and from current Lo (black socket) to input of load.

Rule 2: Connect current Lo to voltage Hi.
Connect all voltage Lo to power line neutral (3 wattmeter circuit)

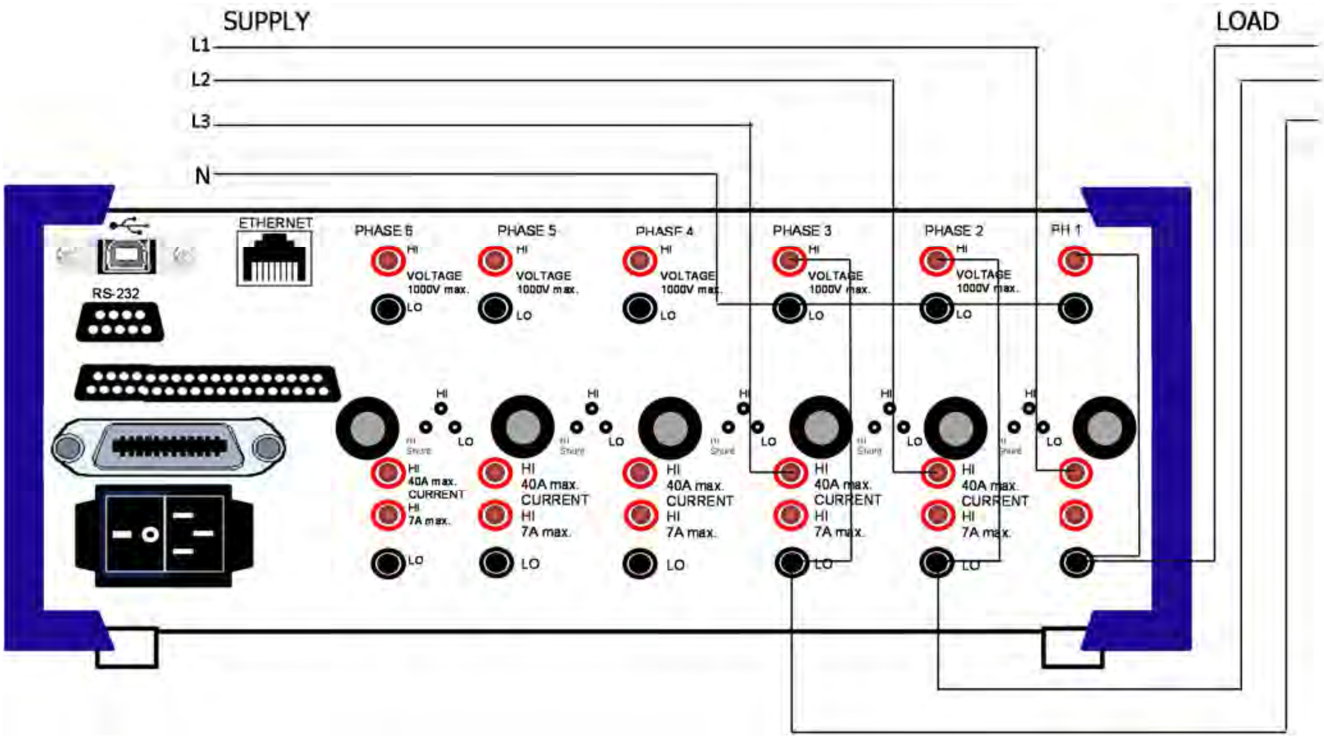


Figure 2.1 Power Measurement in 3-phase mains circuit using three Wattmeter configuration. Rule 1 and Rule 2 apply.

Power values of the 3 phases are all positive. You can verify that power of phase 1 becomes negative by reversing current phase 1.

- **Aron Connection**

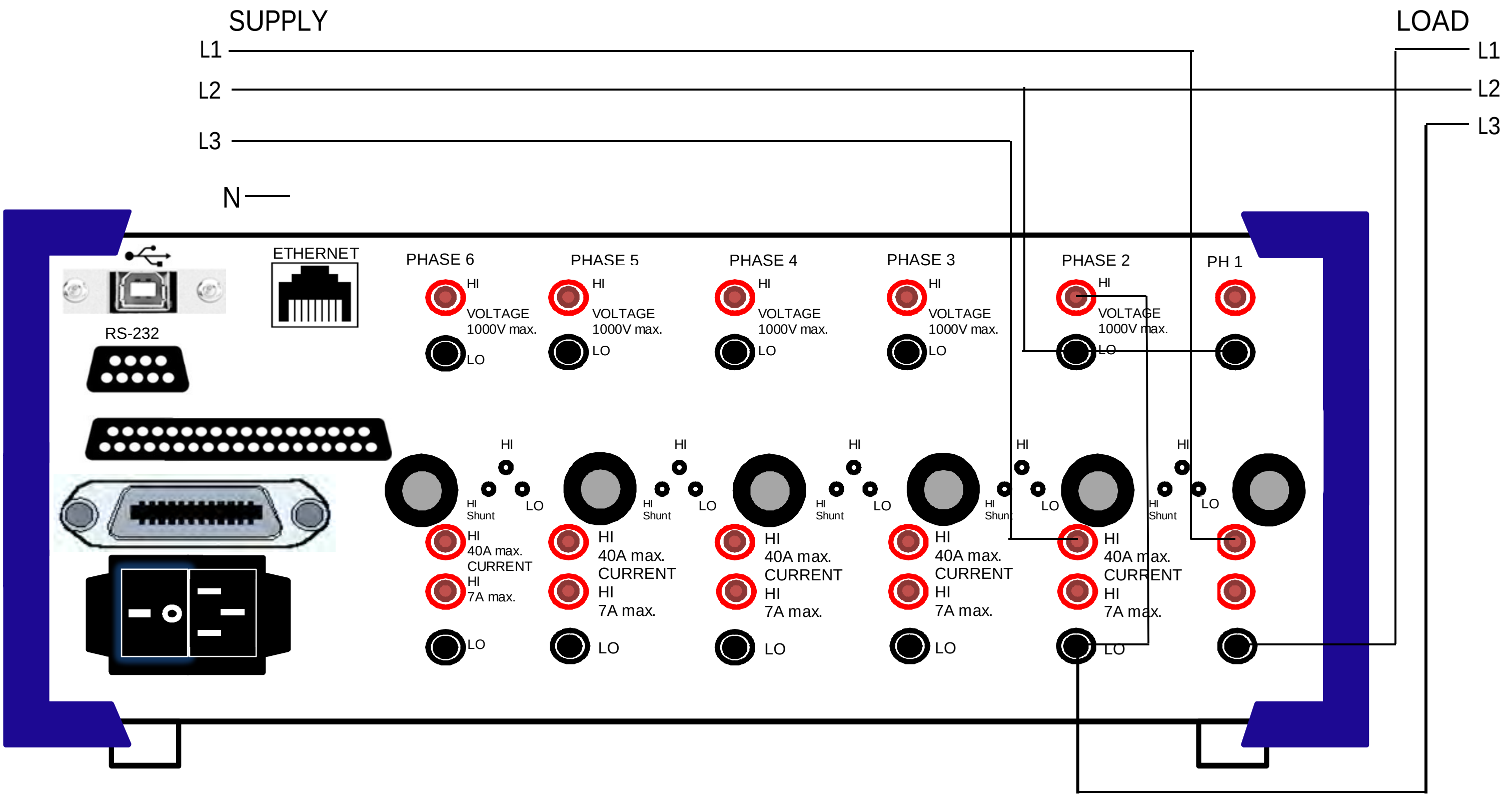


Figure 2.2 Power Measurement in 3-phase mains circuit using 2 Wattmeter configuration. Rule 1 and Rule 3 apply.

Rule 3: Voltage Lo connects to third wire not used for current measurement (Figure 2.2). Phase to Phase voltages are measured.

The 2 Wattmeter circuit measures 2 currents, and 2 line-to-line voltages and determines total power of the 3 phase load. One of the displayed power values can become negative due to phase shifts of inductive loads. This may lead to confusion. Therefore, strictly follow rule 1 and rule 3.

● CONNECTING A 6 PHASE POWER ANALYZER TO 2 MAINS CIRCUITS

Figure 2.3 shows the connections to a 6-phase Power Analyzer using three 30A current inputs and three 1A current inputs from a three phase 0-100A current sensor module. Such current sensors have at 100A primary current a nominal of 50mA output current and therefore require a current scaling factor of 2000 to display actual current and power.

This is how you proceed.

- Make connections as shown in Figure 2.3. Observe Rules 1 and 2 to obtain positive power on all phases. Note: Rms current is positive independent of direction
- Select current input IN5A (Section 4.1: Selecting Current Input)
- Select auto-ranging for current (Section 4.1: Selecting Current Range)
- All six phases are set to IN5A. Phases 1, 2, 3- current actually flow in the 30A input and therefore scaling factors of approximately 60 are required. Phases 4, 5, 6 current actually flow in 1A Input and therefore scaling factor of approximately 0.1 times the scaling factors 2000 of the current sensors must be entered.
  You find the precise scaling factors for your instrument in section 4.1: Selecting Current Input. Use the scaling factors written on the current sensors module
- Enter Setup (Section 4.1: Selecting Setup) and write six current scaling factors

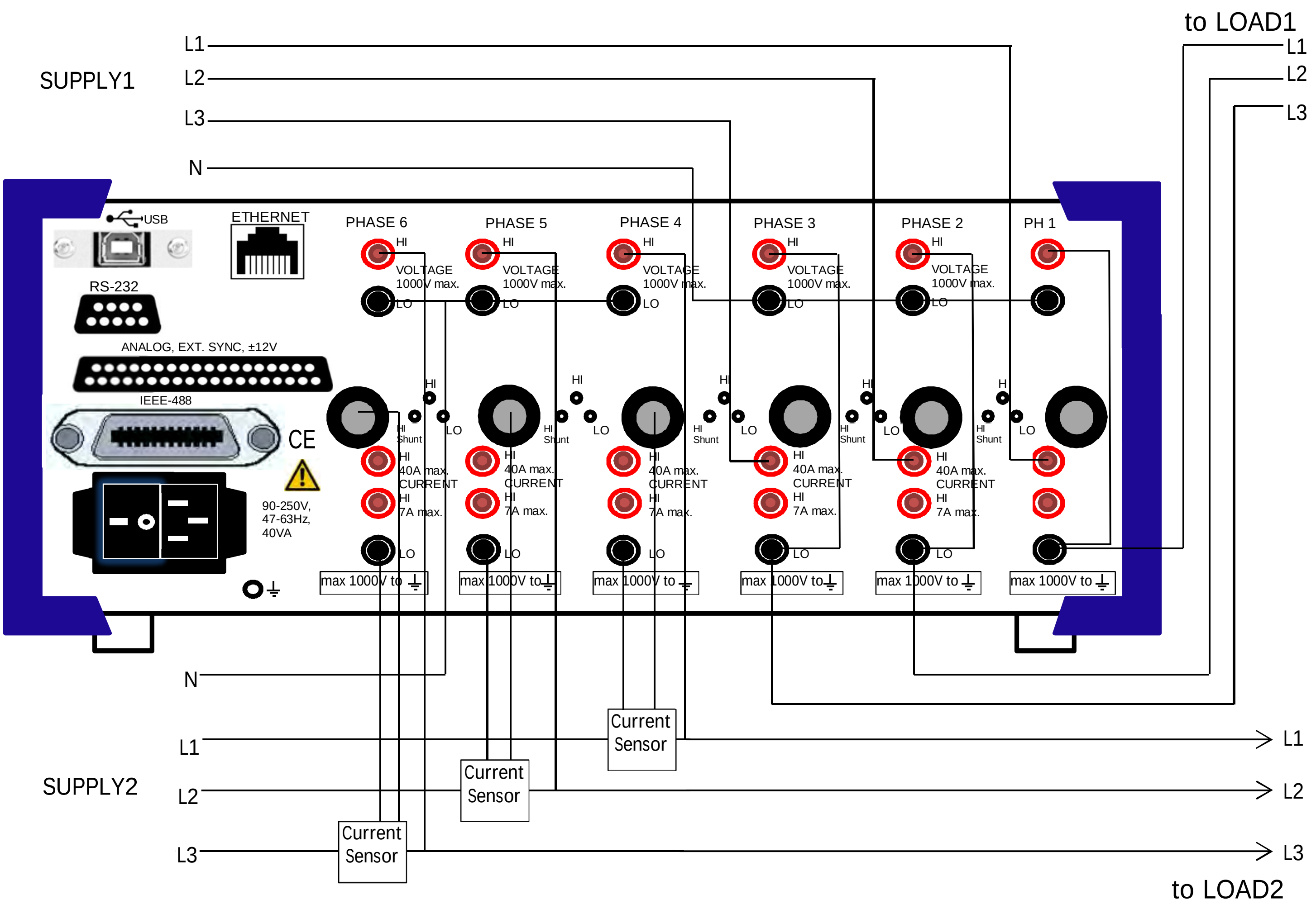


Figure 2.3 Power measurement using three 30A current inputs and three 1A current inputs

3. 2800 MATHEMATICAL DEFINITIONS AND SPECIFICATIONS

3.1 MATHEMATICAL DEFINITIONS

Tables 3.1 and 3.2 define all quantities measured and computed. The “batch” column shows the symbol that must be used in the interface batch command of section 6 (setting the quantities viewed on the display).

Table 3.1. List of standard values that can be displayed

Description	Symbol = Formula, Description	Batch
rms current	Arms = $(1/T\ {}^{T}\!\int_0 A^2\, dt)^{1/2}$, includes all harmonics	A00
mean current	Amean = $1/T\ {}^{T}\!\int_0 A\,dt$, dc-component of current	A01
rectified mean current	Arect = $1/T\ {}^{T}\!\int_0 \|A\|\, dt$, rectified mean current	A02
peak current	Amax = maximum current in time interval	A10
current distortion	Athd1 = $(Arms^2 – A01^2)^{1/2}$ / Arms, use for frequency inverter	A23
harmonic current distortion	Athd2 = $(\Sigma An^2)^{1/2}$ / Arms, n = 2,3, … 40	A25
current crest factor	Acf = Amax / Arms	A20
current form factor	Aff = Arms / Arect, is 1.1107 for sine wave	A22
current fundamental	A01 = fundamental current of FFT	A35
current 2. to 7. harm	A02,A03,A04,A05,A06,A07	A37,A39,A41,A43,A45,A47
current 8. to 13. harm	A08,A09,A10,A11,A12,A13	A49,A51,A53,A55,A57,A59

rms voltage	Vrms = $(1/T\ {}^{T}\!\int_0 V^2\, dt)^{1/2}$, includes all harmonics	A03
mean voltage	Vmean = $1/T\ {}^{T}\!\int_0 V\,dt$, dc component of voltage	A04
rectified mean voltage	Vrect = $1/T\ {}^{T}\!\int_0 \|V\|\, dt$, rectified mean voltage	A05
peak voltage	Vmax = maximum voltage in time interval	A13
lowest voltage	Vmin = lowest voltage in time interval	A12
peak to peak voltage	Vptp = $V_{max} – V_{min}$	A11
voltage distortion	Vthd1 = $(Vrms^2 – V01^2)^{1/2}$ / Vrms, use for frequency inverter	A24
harmonic voltage distortion	Vthd2 = $(\Sigma Vn^2)^{1/2}$ / Vrms, n = 2,3, …, 40	A26

Table 3.1: continued, List of standard value that can be displayed			
Description	Symbol = Formula, Description		Batch
voltage crest factor	Vcf = Vmax / Vrms		A19
voltage form factor	Vff = Vrms / Vrect, is 1.1107 for sine wave		A21
voltage fundamental	V01 = fundamental voltage of FFT		A36
voltage 2. to 7. harm	V02,V03,V04,V05,V06,V07	A38, A40, A42, A44, A46, A48	
voltage 8. to 13. harm	V08,V09,V10,V11,V12,V13	A50, A52, A54, A56, A58, A60	

active power	W = 1/T $^{T}\int_{0}$ u·i dt, total power in W		A06
apparent power	VA = Arms · Vrms, total apparent power VA		A17
reactive power	Var = ±($Papp^2$ – $Pact^2$)$^{1/2}$, reactive power Var		A18
power factor	PF = Pact / Papp, includes all harmonics		A27
fundamental power	W01 = A01 · V01 · cos φ01, φ01 = phase		A28
fund apparent power	VA01 = A01 · V01		A29
fund reactive power	Var01 = ($VA01^2$ – $W01^2$)$^{1/2}$, magnitude only		A30
power 2. to 6. harm	W02, W03, W04, W05, W06	A63, A65, A67, A69, A71	
power 7. to 10. harm	W07, W08, W09, W10	A73, A75, A77, A79	
power of distortion	D = V01(ΣAn^2)$^{1/2}$, n = 2,3, …, 40; D in Watt		A31

energy	Wh = $^{t}\int_{0}$ Pact · dt, active energy in Wh	A14
apparent energy	VAh = $^{t}\int_{0}$ Papp · dt, use it for long term PF	A15
reactive energy	VAR = $^{t}\int_{0}$ Prea · dt, can be positive / negative	A16
battery charge	Ah = $^{t}\int_{0}$ Arect · dt, is positive only	A09
elapsed time	time = $^{t}\int_{0}$ dt, time in hours since RESET	A32

magnitude impedance	Mag Z = V01 / A01 fundamental		A33
phase of fundamental	Phi01 = phase V01, A01		A34
phase 2. to 6. harm	phase 2., 3., 4., 5., 6. harmonic	A64, A66, A68, A70, A72	
phase 7. to 10. harm	phase 7., 8., 9., 10. harmonic	A74, A76, A78, A80,	
frequency	Freq =zero crossing of A, V, Ext; SYNCI, U, Ext		A07

Note: Harmonic values not contained in table 3.1 can be read via interface:
These are: current A14 to A88 and voltage V14 to V88.

Table 3.2: List of special values that can be displayed		
Description	Symbol = Formula, Description	batch
sum1 of power	sum1 = Pact1 + Pact2; phase 1 + phase 2	A81
sum2 of power	sum2 = Pact2 + Pact3; phase 2 + phase 3	
sum3 of power	sum3 = Pact1 + Pact2 + Pact3; phase 1+2+3	
sum4 of power	sum4 = Pact3 + Pact4; phase 3 + phase 4	A82
sum5 of power	sum5 = Pact4 + Pact5; phase 4 + phase 5	
sum6 of power	sum6 = Pact4 + Pact5 + Pact6; phase 4+5+6	
ratio1 of power	ratio1 = Pact2 / Pact1; Phase 2 / Phase 1	A83
ratio2 of power	ratio2 = (Pact1 + Pact2) / Pact3	
ratio3 of power	ratio3 = (Pact3 + Pact4) / (Pact1 + Pact2)	
ratio4 of power	ratio4 = (Pact1 + Pact2 + Pact3) / Pact4	A84
ratio5 of power	ratio5 = (Pact4 + Pact5) / (Pact1 + Pact2)	
ratio6 of power	ratio6 = (P4 + P5 + P6) / (P1 + P2 +P3)	
Motor1 Values from phase 1, phase 2, and phase 3		
Mec input power	Pin = electric power applied to motor	A85
Mec output power	Pout = Pin – Pin at no load in Watt (Loss)	
Torque	Torque = Pout · poles1 / 4 · 3.1416 · frequency1	
Slip	Slip = 1 – fout / fin	A86
rotation per minute	rpm = 120 · frequency1 / poles1	
efficiency	efficiency = 1 – Pin at no load / Pin	
Transformer values from phase 1 and phase 2		
Vrect, rms corrected	Vcorrected = 1.1107 · Vrect	A87
correted power	Corr power = Pact 1 / (0.5 + 0.5 · Vrms / Vcorrected)	
Loss factor Q	Q = tan X/R, where Z=R + jX	

Table 3.2: List of special values that can be displayed

Description	Symbol = Formula, Description	batch
Loss resistance	Equivalent loss resistance = Pact1 / $Arms^2$	A88
Loss inductance	Equivalent loss reactance = Prea 1 / $Arms^2$	
turn ratio	turn ratio = N2 / N1 = Vrms2 / Vrms1, no load	
analog input1	±5V analog input1	A89
analog input2	±5V analog input2	
analog input3	±5V analog input3	
analog input4	±5V analog input4	A90
analog input5	±10V analog input5	
analog input6	±10V analog input6	
V1 line to line	V1 ltl = (V_{1rms} + V_{2rms}) · 0.86603	A93
V2 line to line	V2 ltl = (V_{2rms} + $V_{3rms)}$ · 0.86603	
V3 line to line	V3 ltl = (V_{3rms} + V_{4rms}) · 0.86603	
V4 line to line	V4 ltl = (V_{4rms} + V_{5rms}) · 0.86603	A94
V5 line to line	V5 ltl = (V_{5rms} + V_{6rms}) · 0.86603	
V6 line to line	V6 ltl = (V_{6rms} + V_{4rms}) · 0.86603	
Motor2 Values from phase 4, phase 5, phase 6		
Mec input power	Pin = electric power applied to motor	A95
Mec output power	Pout = Pin – Pin at no load in Watt	
Torque	Torque = Pout · poles / 4 · 3.1416 · frequency2	
Slip	Slip = 1 – fout / fin	A96
rotation per minute	rpm = 120 · frequency / poles	
efficiency	efficiency = 1 – Pin at no load / Pin	

Example:

Assuming you are using a 2-phase Power Analyzer and want to display ratio 1 = Pact2 / Pact1 at the bottom of the display (Figure 1.1). Touch icon, “Ah” (Fig. 1.1). In the value selection table touch “Ratio123” (Fig. 1.2).
In Figure 1.1 at the bottom line you have now 3 quantities displayed: ratio1, ratio2, ratio3, where ratio1 = Pact2 / Pact1, ratio2 = 0, and ratio3 = 0.

3.2 SPECIFICATIONS

Voltage	8 measuring ranges: 0.3 - 1 - 3 - 10 - 30 - 100 - 300 - 1000V	Bandwidth DC-2MHz
	Coupling: AC or AC+DC | Common mode rejection:	100dB at 100kHz
	Input impedance: 1MΩ / 15pF. Floating input.	max. 1000Vrms
	Crest Factor 15:1 at 10 % fs. Typical accuracy at 10 % is 0.1 %.	fs = full scale
	Temperature coefficient: 0.004 % / °C	
% reading + % range	Standard accuracy 23°C ±1°C. 3V to 600V 45 to 65Hz 0.08 + 0.08 3 to 1000Hz 0.1 + 0.1 1 to 10kHz 0.2 + 0.2	High precision 10V to 600V 0.02 + 0.02 0.03 + 0.03 0.1 + 0.1
	10 to 100kHz (0.2+0.2) + (0.2+0.2)· log(f/1kHz)	(0.2+0.2) + (0.2+0.2)· log(f/1kHz)
	DC[1)]//100-500kHz[1)] 0.1 + 0.1// 0.012*f(kHz)	
	Linearity 100V range: 130 % 100 % 50 % 10 % 5 % 130.01V 100.00V 49.988V 10.000V 5.0014V	Typical linearity at 50/60Hz
Current	4 inputs: In30A, In5A, In1A, shunt. Floating inputs. 1 sec averaging	max. 1000Vrms to earth
	In1A: 6 ranges 1.5[1)] - 5 - 15 - 50 - 150 - 500 - 1500mA. DC-100kHz	max. 2A continuous
	In5A: 6 ranges 15[1)] - 50 - 150 - 500mA - 1.5 - 5 - 15A. DC-100kHz	max. 7A continuous
	In30A: 4 ranges 1[1)] - 3 - 10 - 30 - 100A. DC-10kHz	max. 40A/30A cont., 1-3ph/4-6ph
	Shunt: 60 - 200 - 600mV - 2 - 6V. DC-100kHz	max. 30V continuous
	Coupling: AC or AC+DC. | Common mode rejection.	115dB at 100kHz
	Crest factor 15:1 at 10 % fs. Typical accuracy at 10 % fs is 0.1 %.	fs = full scale
	Temperature coefficient: 0.004 % / °C	
% reading + % range	Standard accuracy 23°C ±1°C. **Input** / **In1A,In5A,Shunt** / **In30A** 45 to 65Hz: 0.08 + 0.08 / 0.08 + 0.08 3 to 1000Hz: 0.1 + 0.1 / 0.2 + 0.2	High precision **In1A: 15mA-1A** **In5A: 150mA-5A** 0.02 + 0.02 0.03 + 0.03
	1 to 10kHz 0.15 + 0.15	0.15 + 0.15
	10 to 100kHz (0.15+0.15)+(0.5+0.5) ·log(f/1kHz)	(0.15+0.15)+(0.5+0.5) ·log(f/1kHz)
	DC[1)]//100-500kHz[1)] 0.1 + 0.1// 0.023*f(kHz)	
	Input Koax. 30A (Option) instead of In30A 45 to 65Hz 0.05 + 0.05 3 to 1000Hz 0.08 + 0.08	Exposure of current inputs to their max. value will result in additional errors[1]. In1A: 0.03 % I^2 In5A: 0.003 % I^2 In30A: 0.0001 % I^2 Koax: 0.0001 % I^2
	Input 0-100A precision current sensor (Option 04) connected to In1A input 3 to 100Hz 0.05 + 0.05 100 to 1000Hz 0.1 + 0.1	
	Linearity 500mA range: 130 % 100 % 50 % 10 % 5 % 650.02mA 500.02mA 250.02mA 49.979mA 24.997mA	Typical linearity at 50/60Hz

Power	W range = voltage range times current range	112 power ranges
	Standard accuracy 23° ±1°C **Input** / **PF** / **In1A, In5A, Shunt** 45 to 65Hz / 0-1 / 0.16 + 0.16 3 to 1000Hz / 0-1 / 0.2 + 0.2 1 to 20kHz / 0-1 / 0.2 +(0.2 + 0.08 · k1/0.1kHz) 20 to 100kHz / 1 / % error (A+V)	Hi precision **In1A: 15mA-1A** **In5A: 150mA-5A** 0.04 + 0.04 0.1 + 0.1 0.2 +(0.2 + 0.08 · k1/0.1kHz) % error (A+V)
% reading + % range	DC[1)]//100-500kHz[1)] 1 / 0.2 + 0.2// add %error (V+A)	
	Input / **PF** / **In30A** / **Current Sensor 0-100A** 45 to 65Hz / 0-1 / 0.16 + 0.16 / 0.1 + 0.1 3 to 1000Hz / 0-1 / 0.2+(0.2+0.1·k1/0.1kHz) / 0.2+(0.2+0.1·k1/0.1kHz) DC[1)] / / 0.2 + 0.2 / 0.1 + 0.1	Coax. 30A (Option) 0.08 + 0.08 0.08+(0.08+0.08 · k1/0.1kHz) 0.2 + 0.2
	PF 1 / 0.9 / 0.8 / 0.7 / 0.6 / 0.5 / 0.4 / 0.3 / 0.2 / 0.1 / 0 k1 0.05 / 0.74 / 0.97 / 1.18 / 1.38 / 1.55 / 1.70 / 1.83 / 1.92 / 1.98 / 2.00	k1 = $(2-PF^4) / (1+PF^2)$ 1) Typical max. error
	W Linearity / 130 % / 100 % / 50 % / 10 % / 5 % Volt / 130.00 / 100.00 / 49.985 / 9.9992 / 4.9990 Ampere / 6.5004 / 5.0014 / 2.5020 / 500.82m / 250.40m Watt PF=1 / 844.74 / 500.07 / 125.05 / 5.0056 / 1.2522	Typical linearity of voltage, current and power.
Frequency	SyncA: 2Hz-5kHz, SyncV: 2Hz-150kHz, S_ExtV: 2Hz-150kHz S_ExtV is a TTL output for SyncA/V or a TTL input	Accuracy: 0.05 % Sync for each phase
Shunt	Sensitivity: 60mV/A. For an ext. shunt with 1mV/A scale by 60.0	
Energy	Wh, VAh, Varh, Ah, integration time. Add accuracy % of values involved. Reset sets all values to zero. Integration runs uninterrupted, also in the background.	
Harmonic Analysis	Frequency range of fundamental 3Hz – 15kHz Harmonics: V and A: 1-88; W and phase angle 1-21 Accuracy: Fundamental [1)], use % figures of V, A, W	
Computed Values	Accuracy: Add % figures of values involved	65 values per phase
	Rectified mean, VA, Var, impedance, distortion factor, power factors, motor- and transformer values, sums, ratios, analog inputs and -outputs, speed inputs, and more are continuously updated and ready for display or interface output.	
Four measuring functions	Standard: 1 to 6 phase, measures all electrical values at 0.8s updates or 100ms updates. Logging: Up to 48 values in 20ms, or long time averaging up to 10 minutes. Transient: Simultaneous V-, A-, W-waves on 6 phases, time 0.25 to 16 seconds. Power-Speed: Measures in 20ms intervals V, A, W, VA, Wh, VAh, speed of rotating devices.	
Memory	1G Byte for storing measurement data Memory for storing individual instrument settings.	
Display	TFT color display, 155 x 94mm, 800x480pixels	
Interface	RS232, 9600 Baud - 921.6k Baud. USB-Converter. GPIB, IEEE 488.2 Ethernet USB, for down loading measurement data	
Analog	4 analog inputs ±5V, 2 analog inputs ±10V, 2 TTL inputs 0-150kHz. Individual scaling factors. 12 analog outputs ±5V of A, V, W, PF, Wh, frequency	
Current Sensor	30A current viewing resistor. Replaces standard 30A input. 0-100A broad band current sensor, 3 phase, 0.1 %.	

General Technical Data	
Dimensions	Metal housing HxWxD; 148x355x335mm
Weight	Maximum 7kg, 6-phase.
Display	TFT color display, 155x94, 800x480pixels
Operation	By touch screen, remote mouse or interface
Mains	90-256V, 47-63Hz, 40VA
Warm up time	25 minutes
Calibration cycle	2 years
Inputs	4mm safety sockets, 3 pol Amphenol socket
Temperature range	Operation 2 to 32^{o}C, storage -10 to 50^{o}C
Standards	Electrical safety EN61010-1, 1000V CAT II Emission IEC 61326-1, class B Immunity IEC 61326-1
Dielectric Strength	Line input to case: 1500V ac Measuring inputs to case: 2500V ac Measuring inputs to measuring inputs: 2500V ac

4. OPERATING THE POWER ANALYZER FROM THE FRONT PANEL

Apply line voltage 90Vac to 264Vac, 47 – 63Hz, and turn on rear panel power switch. The Power Analyzer requires 30 seconds for start-up.
Common to all four measurement functions (Standard, Logging, Transient, and Power-Speed) the following actions are needed:

- Select current inputs (IN1A, IN5A, IN30A, SHUNT: 2 touches)
- Select current range, or AUTO ranging (2 touches)
- Select voltage range, or AUTO ranging (2 touches)
- Select measurement synchronization (SyncI, SyncU, Ext, 2 touches)
- Select measurement duration (2 touches)
- Select wave form on or off (2 touches)
- Select HOLD or RUN or coupling AC or DC+AC (1 touch)
- Select FFT-TABLE (harmonics of current, voltage, power and phase angle) of one phase (1 touch)
- Select FFT-BAR of one Phase (1 touch)
- RESET charge, Wh, VAh, Varh, and time (1 touch)
- Select new display page 1, 2, 3, 4, (5) (1 touch), page (5) for harmonics
- Select different value on display line (2 touches)
- Select new measurement mode (2 touches)
- Select scaling A/V, Baud, GPIB address, Cycles, Transient ID, FFT-ID,
- Suppress, time, save setup, load setup.
  Scaling of analog inputs and frequency inputs.
  (Example Scaling I3: 2000.5 needs 9 touches).
- Select display of phase L1-L3 or L4-L6 (1 touch)

Important: It is possible to use different current inputs on different phases for all measurement modes. Please refer to section 4.1: Selecting Current Input for detailed information.

4.1 OPERATIONS IN STANDARD MEASURE MODE

The Power Analyzer starts up in Standard Measure Mode as shown in figure 4.1. The touch control buttons to the right and at the bottom set operating conditions, and the control buttons to the left set display quantities. The buttons are controllable by a click of the mouse, or by a touch using the supplied pointer, or just using a finger.

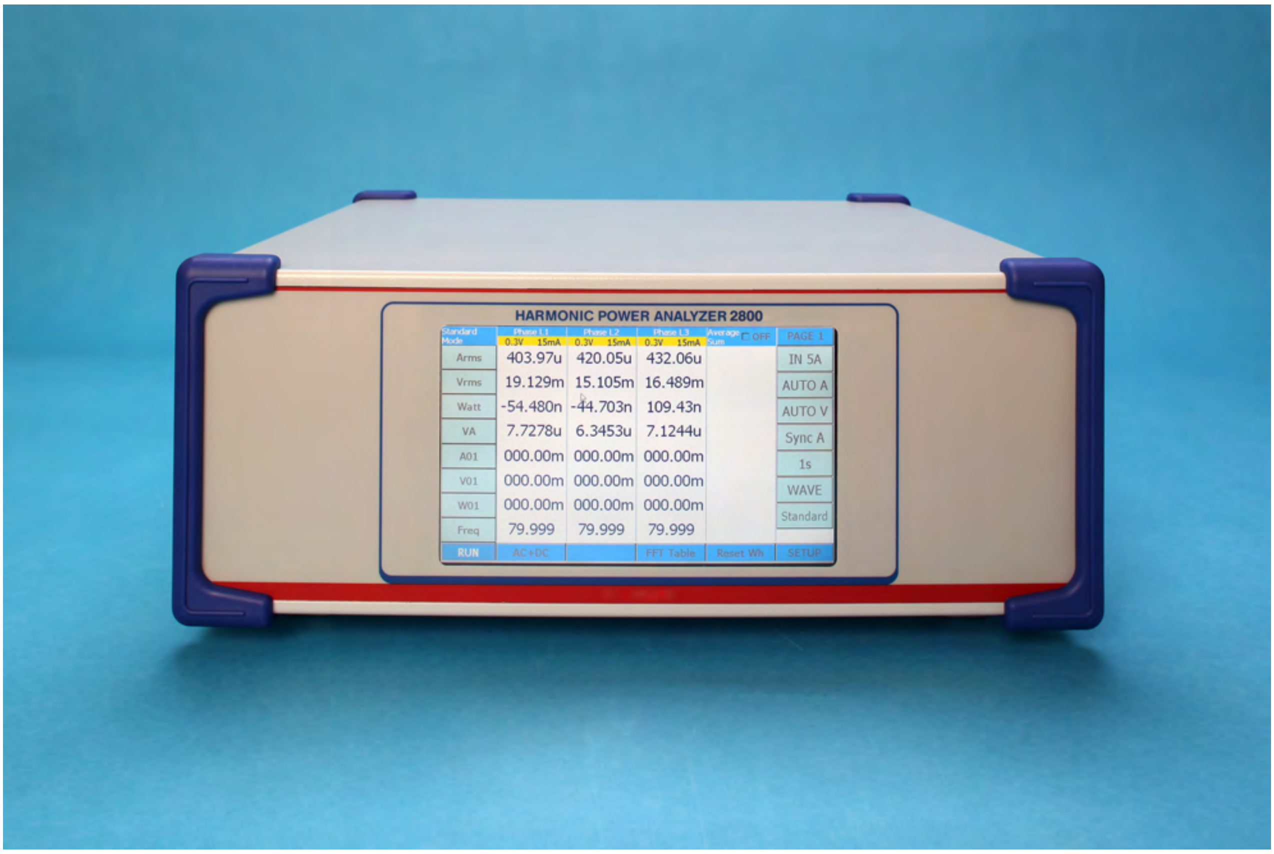


Figure 4.1 Start-up configuration of Power Analyzer

Along the top of the display you find voltage- and current range information as well as over (red)- and under (yellow) range indication.

- **Selecting Measure Mode**

  Touch Standard → pop-up window

Standard	Default
Logging	
Transient	
P-Speed	

  Touch desired Measurement Function

- **Selecting Current Inputs using same Inputs for all Phases**

  Touch IN 5A → pop-up window

IN 1A	
IN 5A	Default
IN 30A	
SHUNT	

  Touch desired current input

- **Scaling Currents using different Inputs**

  The Power Analyzer can be operated using different current inputs simultaneously. For this, select current input IN5A and current auto-ranging. Below the individual scaling factor are listed and must be entered in the Setup. For additional information please refer to section 2, "Connecting a 6 Phase Power Analyzer to two mains Circuits".

  Example Set of Scaling Factors

Input	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
In 1A	0.09846	0.09848	0.09889	0.09819	0.09879	0.09867
In 5A	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
In 30A	59.722	59.948	59.956	59.475	59.704	60.224
Shunt	- -	- -	- -	- -	- -	- -

Actual Scaling Factors for Instrument Serial Number: ....

Input	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
In 1A						
In 5A						
In 30A						
Shunt						

Current scaling factors of external current transducers must be multiplied by above scaling factors

- **Selecting Current Range**

The available ranges depend on the current input selected.
IN1A: 1.5mA, 5mA, 15mA, 50mA, 150mA, 500mA, 1.5A.
IN5A: 15mA, 50mA, 150mA, 500mA, 1.5A, 5A, 15A.
IN30A: 1A, 3A, 10A, 30A, 100A.
SHUNT: 60mV, 180mV, 600mV, 2V, 6V.

Touch AUTO A → pop-up window

15mA	
50mA	
150mA	
500mA	
1.5A	
5A	
15A	
AUTO A	Default

Touch desired current range. Power Analyzer
Is now in manual current ranging.
"AUTO A" selects automatic current ranging.

- **Selecting Voltage Range**

Touch AUTO V → pop-up window

0.3V	
1V	
3V	
10V	
30V	
100V	
300V	
1000V	
AUTO V	Default

Touch desired voltage range. Power Analyzer
is now in manual voltage ranging.
"AUTO V" selects automatic voltage ranging.

- **Selecting Measurement Synchronization**

  Touch [Sync A] → pop-up window

Sync A	2Hz-5kHz Default
Sync V	2Hz-150kHz
S_Ext V	2Hz-150kHz

Touch desired measurement synchronization.
For precise AC-measurements at low frequencies
a periodic wave form is required. If you are measuring voltages only, you must select Sync V. If you are measuring current only, you must select Sync A.
The fundamental of a periodic wave must be in the range 2Hz – 15kHz.

- **Selecting Averaging Time**

  Touch [1sec] → pop-up window

Fast	
500ms	
1s	Default
2s	
8s	
32s	

Touch desired averaging time.
Arms, Arect, Amean, Vrms, Vrect, Vmean,
W, VA, Var, and Frequency are averaged over selected time.

Display update occurs at 0.8 sec intervals also in the “Fast” mode.
Fast: New data are available at 100ms intervals. “Fast” mode can be used to read new data via interface at the rate of 10 datasets per second.

- **Selecting Display Pages**

  Touch [PAGE 1] → increments to [PAGE 2]   Default: Page 1

→ Touch [PAGE 2] → increments to [PAGE 3]

→ Touch [PAGE 3] → increments to [PAGE 4]

→ Touch [PAGE 4] → resets to [PAGE 1]

Every PAGE displays 8 user programmable measurement quantities. Programmed quantities on a display line are valid for all phases L1 … L6.

- **Selecting Wave Forms (Graph)**

Touch WAVE → pop-up window for 3-phase instrument.

Wave 1
Wave 2
Wave 3
-
-
-
OFF

Touch desired phase L1, L2, or L3. Touch OFF to exit wave display.

The lower 3/8 of the display shows current- (blue), voltage- (black), and power waveforms (red) of selected phase. For a consistent display a periodic zero crossing is required.
Note: When displaying waveform the button “FFT Table” is greyed (disabled).

- **Selecting Display L1 to L3 and L4 to L6**

Power Analyzers for 4-, 5-, or 6 phases have the choice to select display of L1 to L3 or L4 to L6.
Touch L1 - L3. The button toggles to L4 - L6.

- **Selecting FFT Table and FFT Bar Graph**

Touch FFT Table. The button will toggle to FFT L1. At the same time the button FFT Bar is activated which lets you select the bar graph of phase L1.

This action will display harmonics of current, voltage, power, and phase on 5 pages (PAGE H1, H2, H3, H4, H5). Harmonics 1-40 of current and voltage, and harmonics 1-20 for power, and phase angle. Phase angle is displayed in a range $\pm 180^o$.

Touch FFT Bar. This displays harmonic bar graphs in percent of fundamental of current, voltage, and power. Touching FFT Bar a second time turns off the bar graph.

Touching FFT L1 will increment it to FFT L2, to FFT L3 and so on up to the number of phases installed and will return to FFT Table

- **Selecting AC or DC+AC-Coupling**

Touch AC+DC, the button toggles to AC.

AC: Arms, Vrms, W, and VA are measured excluding DC.
Amean and Vmean are independent of AC, or AC+DC

DC+AC: Arms, Vrms, W, and VA are measured including DC.

Reminder: The rms value of a 50Hz component and a DC component is equal to the Square root of (50Hz component squared + DC component squared).

- **Selecting Display RUN and Display HOLD**

  Touch RUN, the button toggles to HOLD.

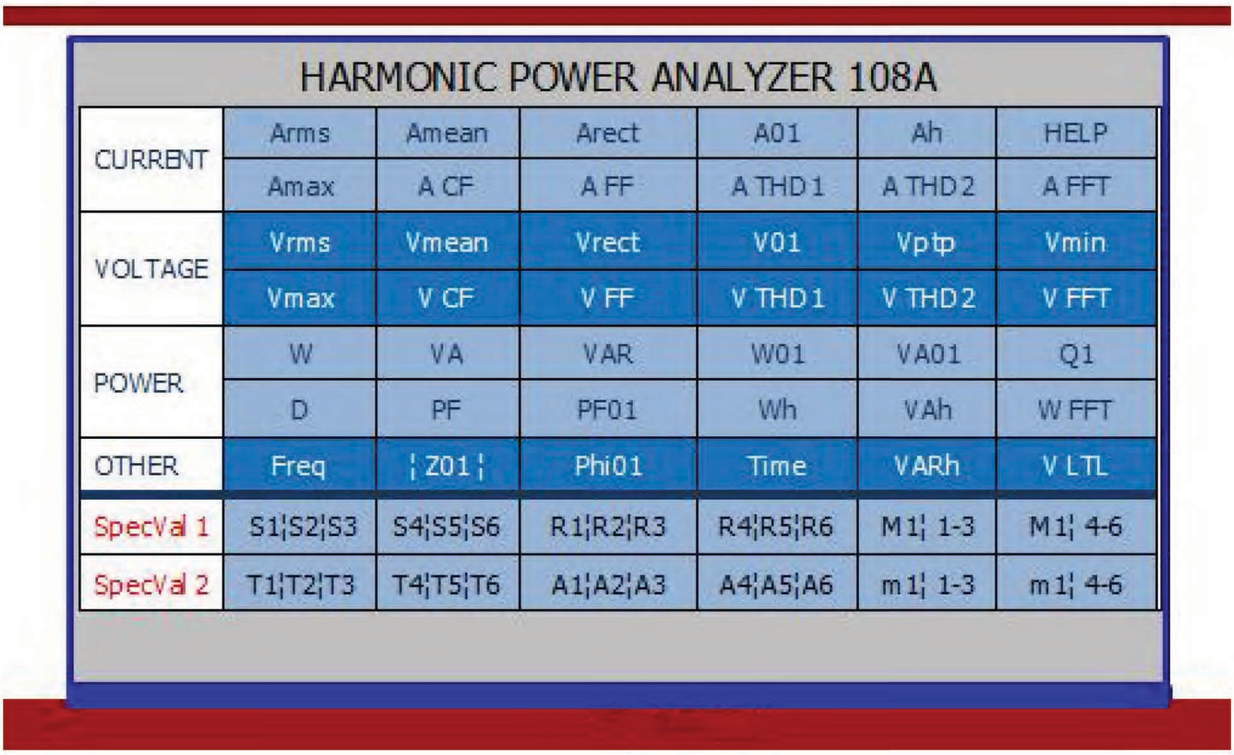
  The display update is halted. In the background the continuous measurement process goes on. This guarantees correct energy- and charge measurements (Wh, VAh, Varh, Ah).

- **Resetting Energy**

  Touch Reset Wh. This will reset all energies, charge, and time (Wh, VAh, Varh, Ah, time).

- **Selecting Display Quantities**

  Touch one of the 8 buttons to the left of the display. This pops-up the value selection table (Figure 4.2). Touch the button of the desired quantity. This will replace the previously displayed quantity with the new one.



HARMONIC POWER ANALYZER 108A

CURRENT	Arms	Amean	Arect	A01	Ah	HELP
	Amax	A CF	A FF	A THD1	A THD2	A FFT
VOLTAGE	Vrms	Vmean	Vrect	V01	Vptp	Vmin
	Vmax	V CF	V FF	V THD1	V THD2	V FFT
POWER	W	VA	VAR	W01	VA01	Q1
	D	PF	PF01	Wh	VAh	W FFT
OTHER	Freq	¦ Z01 ¦	Phi01	Time	VARh	V LTL
SpecVal 1	S1¦S2¦S3	S4¦S5¦S6	R1¦R2¦R3	R4¦R5¦R6	M1¦ 1-3	M1¦ 4-6
SpecVal 2	T1¦T2¦T3	T4¦T5¦T6	A1¦A2¦A3	A4¦A5¦A6	m1¦ 1-3	m1¦ 4-6

Figure 4.2 Value Selection Table of all available quantities which can be displayed.
Touching “A FFT”, “V FFT”, or “W FFT” lets you select Harmonics 1 to 14.
Touching “HELP” pops up the help window explaining the special values.

Exception 1: Touching A FFT, V FFT, or W FFT will activate a pop-up window from which you can select one out of the first 14 harmonics.

Exception 2: Touching one of the special values at the bottom of the value selection table, such as S1¦S2¦S3, will always display 3 values, some of them may be zero

Special values are:

SUMS:	S1¦S2¦S3, S4¦S5¦S6; Definition Table 3.2
RATIOS:	R1¦R2¦R3, R4¦R5¦R6; Definition Table 3.2
MOTOR1:	M1¦1-3, M2¦4-6; Definition Table 3.2
TRANSFORMER:	T1¦T2¦T3, T4¦T5¦T6; Definition Table 3.2
ANALOG:	A1¦A2¦A3, A4¦A5¦A6; Definition Table 3.2
MOTOR2:	m1¦1-3, m2¦4-6; Definition Table 3.2

The HELP button defines the display quantities in a pop-up window. Figure 4.3 Definition of Special Values.

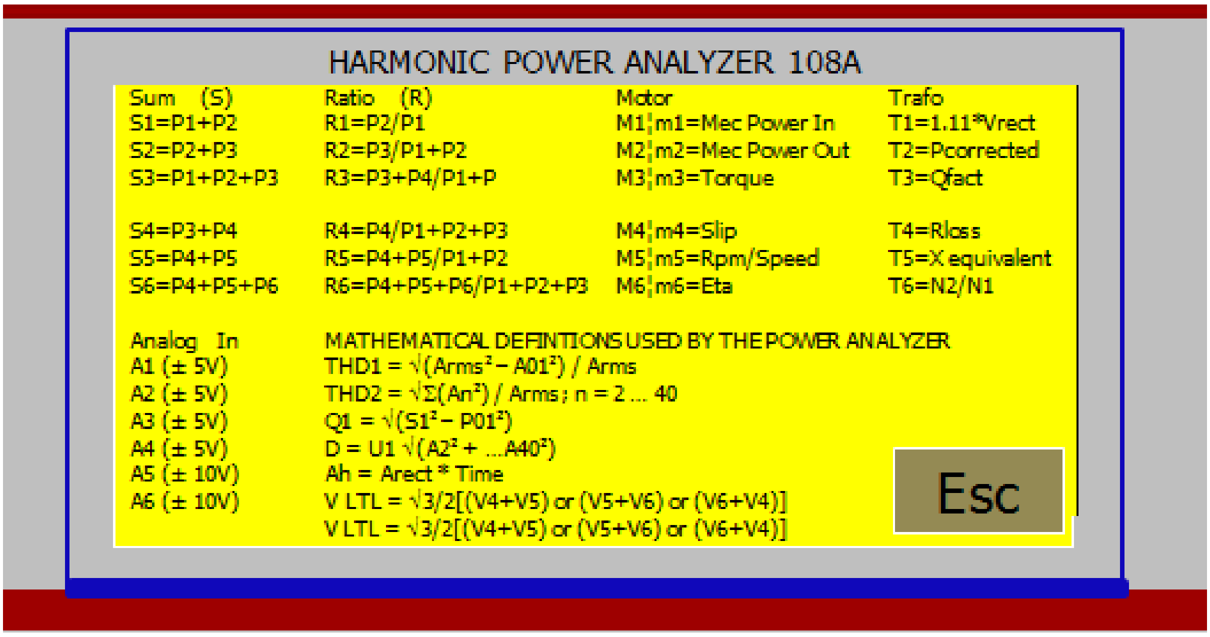


Figure 4.3 Help Table defining sums, ratios, motor1- and motor2 values, transformer values, analog inputs, and harmonic distortion.

- Motor Testing: Motor 1 values from phase 1, 2, and 3.
  Motor 2 values form phase 4, 5, and 6.

  A three phase Power Analyzer calculates 6 motor values (motor 1). To display these values select M1¦1-3 on one display line and M1¦4-6 on the next display line. Speed in rpm must be entered via analog input-output at speed 1/ freq 1 input terminal (Section 7). A rotating disc with 180 divisions yields rpm (rotation per minute).
  A disc with 90 divisions requires multiplication by 2 to obtain true rpm. An external torque transducer can be applied to one of the 6 analog inputs and can be display by selecting either A1¦A2¦A3 or A4¦A5¦A6¦ from the value selections table.

  For motor testing you must enter the number of motor poles, the scaling factors for rpm, and, if used, the scaling factors for external torque transducer.
  Use the RS-232 interface and connect it to a PC in terminal mode. Write following commands to the Power Analyzer.

Write number poles=6:	Command (Commands Section 5) acq:nr_pole1 6→CR LF
Write scaling rpm1 (2.0)	Dis:rpm_sc1 2.0→CR LF
Write scaling torque 1 10.1 (using analog input 1)	Dis:an_sc1 10.1→CR LF
Motor 1 is running at no load. Send the command. Power loss of motor 1 is stored and from now on the motor 1 output power is reduced by this loss.	Comp:mot1_Loss? 6 values are sent from the Power Analyzer to the PC. From now on the motor 1 output power is reduced by motor 1 loss.

A six phase Power Analyzer calculates motor values of two motors simultaneously. Motor 1 values from phase 1, 2, and 3. Motor 2 values from phase 4, 5, and 6. Display motor 2 values by selecting m1¦1-3 and m1¦4-6 in the value selection table. Use the speed 2/ freq 2 input for motor 2 rpm determination; a disc with 180 divisions yields rpm, needs no rpm scaling.
An external torque transducer for motor 2 could be applied to analog input 2, or any other of the 6 analog inputs.
Just like setting the parameters of motor 1 you must enter parameters for motor 2.

Write number poles = 4 : acq:nr_pole2 4 → CR LF

Write scaling rpm 2 (4.0) : dis:rpm_sc2 4.0 → CR LF

Write scaling torque 2 (8.5) : dis:an_sc2 8.5 → CR LF

Motor2 is running at no load. Send the command. Power Loss of motor2 is stored And from this time on motor2 output power is Reduced by motor2 loss	Comp:mot2_loss? 6 Motor Values are returned to the PC. From this time on motor2 output power is reduced by motor2 loss.

Alternatively the scaling of analog inputs, rpm1 (freq 1) and rpm2 (freq 2) can be entered via SETUP described on next page.

- **Selecting SETUP**

Touch SETUP. The pop-up window, shown in Figure 4.4 lets you select the following instrument parameters:

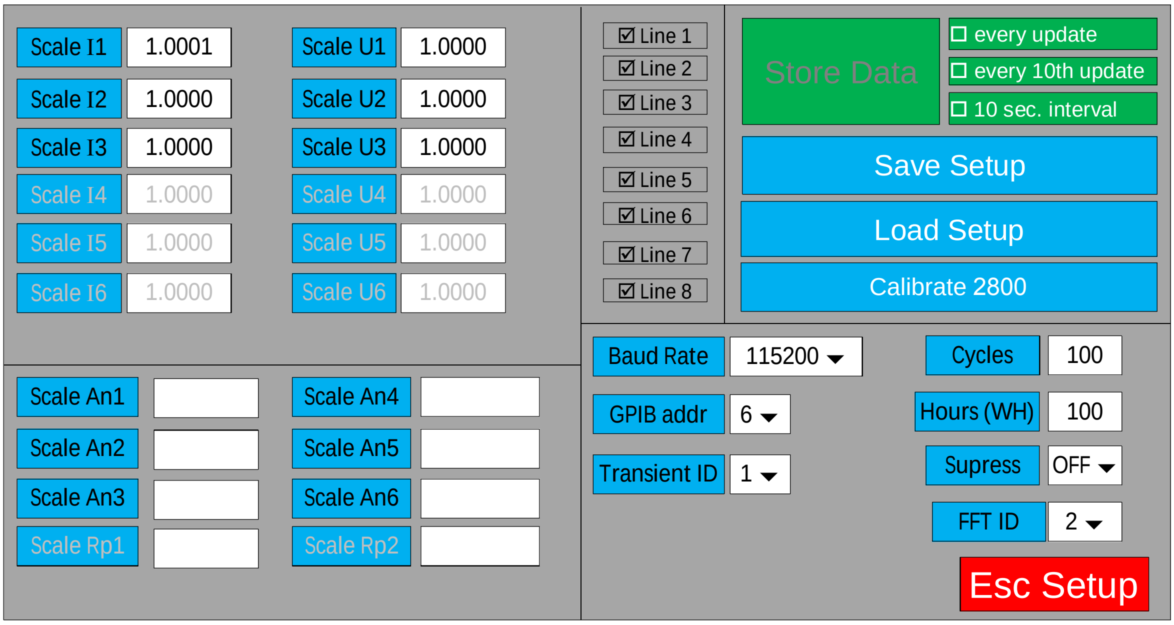


Figure 4.4 Setup Window for selecting instrument parameters

Scaling I1-6: Individual current scaling factors of every phase. Use pop-up number pad. Format 2000.8.

Scaling U1-6: Individual voltage scaling factors of every phase. Use pop-up number pad. Format 9.9427.

Scaling An1-An6: Individual analog scaling. Use pop-up number pad. Format 10.0.

Scaling rpm1-rpm2: Individual TTL freq1/rpm1 and freq2/rpm2 scaling. Use pop-up number pad. Format 2.0.

Cycles: For Logging Measure Mode set 1 to 32000. Defines the measurement duration per measurement set. Use pop-up number pad. Format 160.

Suppress: Toggles on and off. If on, small values of Arms, Vrms, and Watt are set to zero.

FFT ID: Set to 0, 1, 2, 3, 4. Corresponds to FFT averaging over 4, 16, 64, 256, or 1024 cycles.

☐Line1…☐Line8: Serves 2 functions: If deselected display line is off. If selected display line is on, and in case data storing is also on the values are stored in memory. Stored data can be downloaded via USB to a PC.

Store Data: Select the desired storing mode

Transient ID: Set it to 0, 1, 2, 3, 4, 5, or 6. The transient ID determines the measurement duration after start.

Transient ID	Measurement duration	
1	0.25 seconds	
2	0.5 seconds	default
3	1 second	
4	2 seconds	
5	4 seconds	
6	8 seconds	
7	16 seconds	

Hours (Wh): Set time for Wh, VAh, Varh, and Ah summation. Touch [Reset Wh] button to start the energy summation
When time is reached the displayed energy values are held.
The energy summation goes on in the background. Selecting RUN will display the uninterrupted energies.

Baud rate: Set Baud ID to 0, 1, 2, 3, 4, 5, 6, 7, 8.
The Baud ID corresponds to:

Baud ID	Baud Rate	
0	9600	
1	19200	
2	38400	
3	57600	
4	115200	default
5	230400	
6	460800	
7	921600	

GPIB addr: Set 1 to 31. Use pop-up number pad.

Save Setup: Give the setting your personal number

Recall Setup: Recall your setting number

Calibration: Enter your personal code if okay → [Current Cal on]
→ [Voltage Cal on]

4.2 OPERATIONS IN LOGGING MEASURE MODE

- Touch Standard → pop-up window

Standard
Logging
Transient
P-Speed

Touch Logging to switch to Logging function
Measure Mode
The logging mode configures the display, line 1 to line 8, as follows: Frequency, Arms, Vrms, W, PF, VA, Wh, and VAh. These values are fixed; there is no access to the value selection table

Caution: Before touching START a valid synchronization signal must be applied to the Power Analyzer inputs. Not doing so the Power Analyzer may stall. Turn power off and restart again.

- **Valid Synchronization**

A valid synchronization for Logging is current or voltage, or both applied to every phase of the Power Analyzer. The synchronization frequency must be in the range 5Hz to 2kHz for current (Sync A), 5Hz to 10kHz for voltage (Sync V).

DC-current and DC-voltage can be measured too (DC-motors). For DC use an external TTL synchronization (5Hz to 10kHz), apply it to the rear panel Sync1, Sync2, … Sync6 inputs and select "S_Ext V".

Example: 2-phase Power Analyzer: Connect Sync1 and Sync2 to TTL-signal.
3-phase Power Analyzer: Connect Sync1, Sync2, and Sync3 to TTL-signal.

- **Selecting CYCLES**

  Touch SETUP. In the pop-up window Figure 4.4

  Touch CYCLES. Use the pop-up number pad. Enter the number of Cycles, minimum 1, maximum 32000.

  Hint: number of cycles divided by applied frequency must be greater than 10ms
  Also, use a high RS232 baud rate for fast data transmission.

- In Logging Measure Mode 8 values per phase are measured. These are: frequency, Arms, Vrms, W, PF, VA, Wh, and VAh.
  The buttons to the left of the display are deactivated (greyed). There is no access to the value selection table.

- Logging can be started from the display or from the computer interface.

WHAT HAS TO BE OBSERVED WHEN USING LOGGING?

- A valid synchronization signal must be applied before pressing START.
  or before sending the interface command acq:go.

- Cycles divided by frequency of synchronization determines the time for one measurement.
  Example: "Cycles" set to 1, frequency of synchronization is 50Hz (1/50Hz = 0.02sec).
  Time interval for one measurement = 0.02 sec.
  If "cycles" is set to 30000 the time for one measurement is
  30000 · 0.02 sec. = 10 minutes.

- At end of time interval (Cycles divided by synchronization frequency) data from all phases (max. 6) are sent via RS232 to an external computer, and to the display to display it and/or store data in memory. This process repeats until stopped.

- For fast data acquisition use manual ranging. Select ranges such that no severe overloads occur.

- To transmit data from a 6-phase Power Analyzer via RS232 to a PC within 20ms (time interval for measurement) the Baud Rate of 460800 Baud must be selected.

- To catch data from a short term transient process we recommend: Start Logging and slightly delayed start the process.

- Measurements on frequency inverters must be synchronized to current or to an external frequency. Do not use synchronization to voltage.

- In Logging Measure Mode the display updates in 0.8 second intervals.

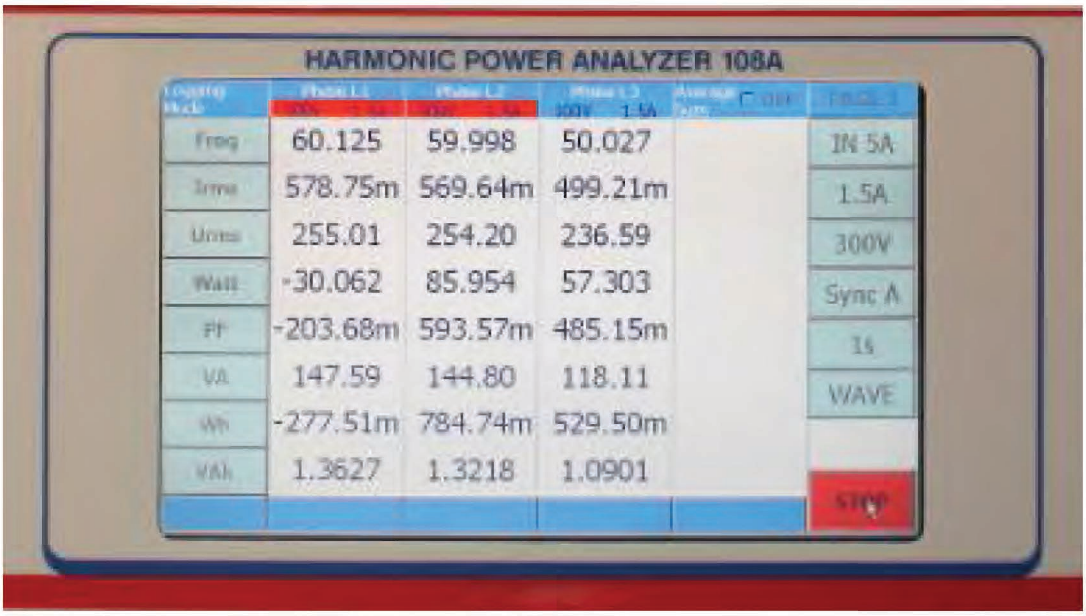


Figure 4.5: 2800 display in Logging Mode.

4.3 OPERATIONS IN TRANSIENT MEASURE MODE

- Touch Standard → pop-up window

Standard
Logging
Transient
P-Speed

Touch Transient to switch to the Transient Measure Mode

- Touch SETUP → touch Transient ID. Select 0, 1, 2, 3, 4, 5, or 6.

Transient ID	Transient Measurement Duration
1	0.25 seconds
2	0.5 seconds default
3	1 second
4	2 seconds
5	4 seconds
6	8 seconds
7	16 seconds

WHAT IS MEASURED IN TRANSIENT MEASURE MODE?

Upon touching the START button all phases begin measurement at the same time. The start delay between different phases is less than 1 microsecond.
The duration of measurement is determined by the SETUP variable “Transient ID”. Default Transient ID = 2 corresponds to 0.5 seconds measurement time. If required, you can scale currents and voltages.

Every phase samples current, voltage, and power. The time relation between phases is precisely maintained. When measurement is done, all wave forms are displayed. Touching a zoom sector allows for enlargement of up to 256 times. Select L4 to L6 to display wave forms of phases L4, L5, L6.
Touch BACK to return to the original wave forms.

TWO WAYS TO USE TRANSIENT MEASURE MODE

- **Quick viewing of wave forms in Standard Measure Mode**.

  Touch Standard, touch Transient, touch START.

Assuming you are measuring in a 50Hz/60Hz 3-phase system you obtain on one pitch all wave forms. Zoom once to obtain 5 to 6 periods of all wave forms in precise phase relation to each other. This is assuming you have selected Transient ID = 2.
If you wish zoom more to view details.

Touch Transient, touch Standard to return to previous measure mode.

- **View Wave Forms of System in Transient State**

  The system can be 1 to 6 phase:

  - 3 phase or multi-phase rotating device being started or being loaded.
  - DC motors starting or being loaded.
  - Accelerating or recuperating electric cars.
  - Start-up behavior of large electromechanical system.

- For this kind of measurements you must use broad band current sensors and must select AC+DC coupling of the Power Analyzer.

- Select Transient ID that fits best to your measurement.

- You must select proper current- and voltage ranges, to avoid serious overloads

- Start the transient measurement then start your system.

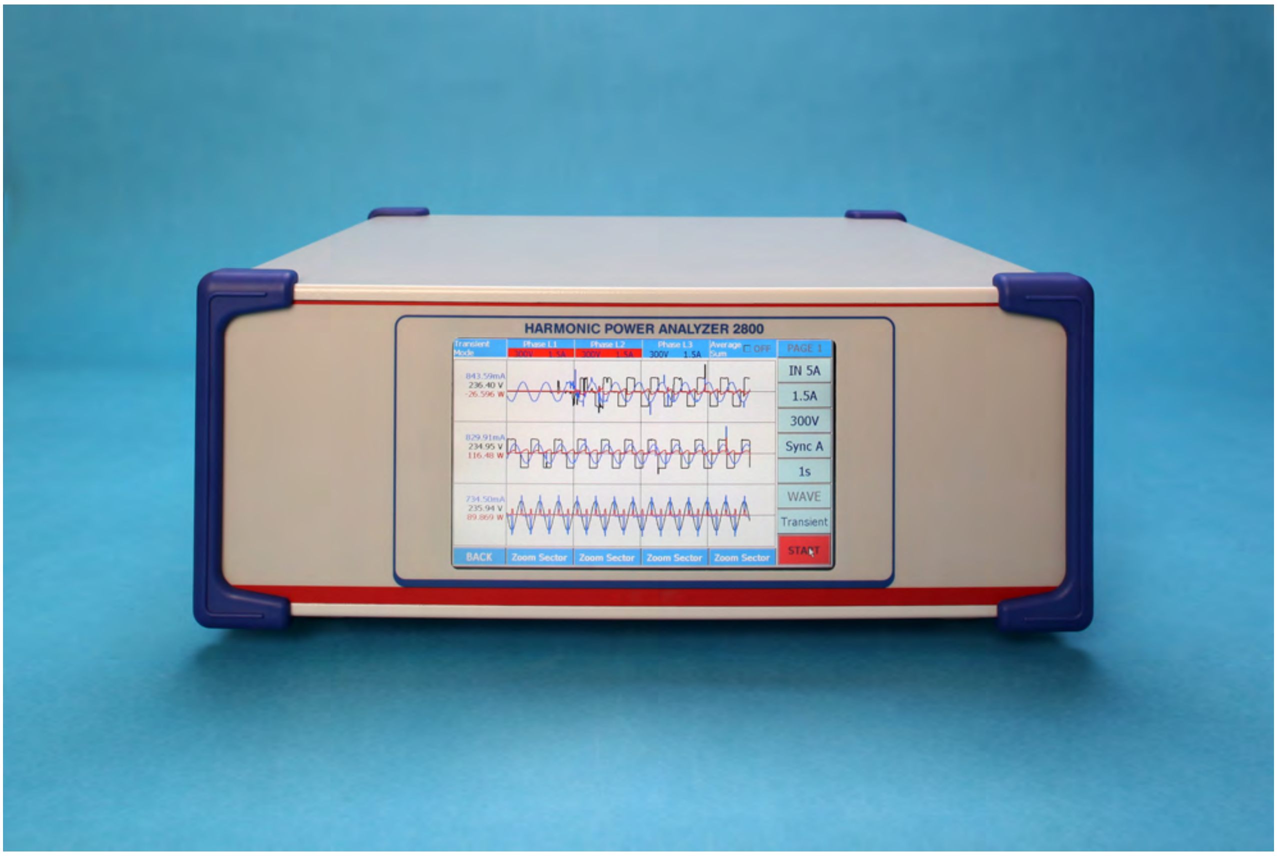


Figure 4.6 Shows the transient display of a 3-phase Power Analyzer.

The three values to the left are rms current, rms voltage, and average power of the displayed wave forms.

4.4 BASICS OF POWER-SPEED MEASURE MODE

Power – Speed measurements are performed using phase 1, or using phase 1 and phase 2, or using phase 1, phase 2, and phase 3. The external speed information is applied to the TTL speed1 input of the analog input- output option. If not installed the speed will be zero. Use an optical speed sensor with a rotating disc of 180 divisions. Apply its TTL-output to the speed1 input to obtain speed values in rpm (rotations per minute). The range of frequency of the TTL speed1 input is 20Hz to 150kHz. Maximum rpm with a disc of 180 divisions is (150000 / 180) 60 = 50000 rpm.

WHAT IS MEASURED IN POWER-SPEED MEASURE MODE

The Power Analyzer input can be DC from a battery, or AC from power line, or AC from frequency inverter. Upon START the Power Analyzer measures in 20ms time intervals Arms, Vrms, Wtotal, VAtotal, Whtotal, VAhtotal, and rotating speed in rpm (rotation per minute). Where Arms and Vrms are averages of 3 phases, of 2 phases, or one phase.

When the START button is touched analog output1 is set 20ms later from 0V to 5V. It can be used to activate the system under test. Datasets are stored in internal memory.

Upon pressing STOP measured values versus time are displayed. Maximum duration of power – speed measurement is 10.7 seconds, amounting to 535 datasets in 20ms time increments. This time is sufficient to monitor the start of an electric car. Values such as current peaks, voltage dips, consumed energy, maximum speed, and maximum acceleration are parameters of interest to the manufacturer.

OPERATIONS IN POWER-SPEED MEASURE MODE

- Touch Standard → pop-up window

Standard
Logging
Transient
P-Speed

  Touch P-Speed to switch to the Power-Speed Measure Mode.

- Set Voltage range according to supply voltage applied to load under test

  Touch AUTO V → pop-up window

0.3V
1V
3V
10V
30V
100V
300V
1000V
AUTO V

  Touch appropriate voltage range
  (Do not use AUTO V).

- Set current input. You must set the current range based on the estimated maximum rms current. Many applications experience currents larger than 40A. If so, use external current sensors capable of transmitting DC currents.

Example: *Estimated current is 100A. A 3-phase current sensor module 0-100A, DC to 100kHz, with output 50mA at 100A primary current is used. Select Current Input In1A and range 50mA.*

  Touch IN 5A → pop-up window

IN 1A
IN 5A
IN 30A
SHUNT

  Touch IN 1A. Use the 1A-adapter.
  Connect it to the rear panel 3 pole socket.

- Set current range

  Touch AUTO A → pop-up window

1.5mA
5mA
15mA
50mA
150mA
500mA
1.5A
AUTO A

  Touch 50mA to select desired current range.
  (Do not use AUTO A)

- Enter the SETUP window. Set phase 1, 2, and 3 scaling factors by entering the scaling factor written on the 3-phase current sensor module

- Touch START and turn on the system under test.
  Alternatively start your system by using the 0 to +5V signal of analog output1.

- After system reached steady state
  Touch RUN ⊠ returns to STOP and Power Analyzer will plot seven functions versus time. Four functions at the top (voltage, current, power, speed), and three functions at the bottom of the display (energy, apparent power, apparent energy).

- Touch ZOOM Sector to expand desired parts of the functions.

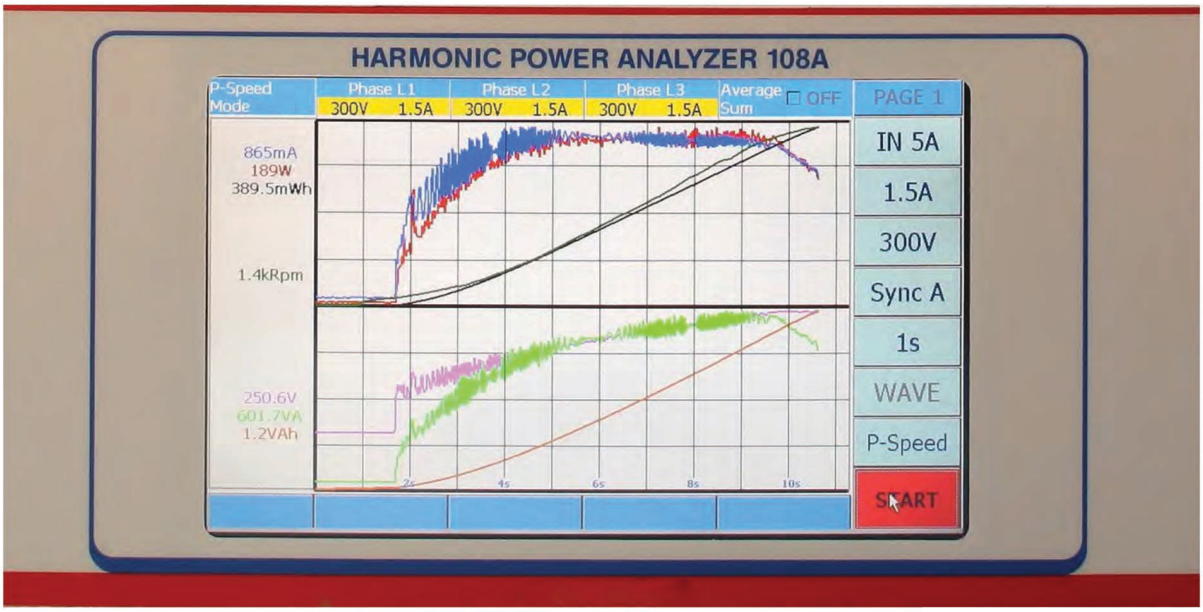


Figure 4.7 Graphs of Current, Voltage, Power, Apparent Power, Energy, Apparent Energy and rotating speed versus time.

- The left side of the display shows maximum values of Arms, power, energy, rpm, Vrms, Wh, and Vah during the run.

5. OPERATING THE POWER ANALYZER USING A COMPUTER INTERFACE

The following interfaces are available:

- USB for wireless mouse
- IEEE-488 on rear panel using the Computer Interface Command Set.
- RS232 on rear panel using Computer Interface Command set.
- RS232 on rear panel with RS232 to USB converter built into RS232 interface cable
- USB interface on rear panel to download measurement data to a PC
- Ethernet interface on rear panel
- 6 analog inputs and two TTL inputs 0-150kHz for external transducers

WHAT HAS TO BE OBSERVED WHEN USING AN INTERFACE

The RS232 cable must be one-to-one connected. Use shielded cables.

Keep interface cables at least 10cm from Power Analyzer current- and voltage input cables. Current- and voltage transients may couple into interface cables and can cause communication errors or even failure.

Every command must be terminated with CRLF (carriage return, line feed) or with EOI (end or identify) using IEEE-488.

WHAT HAS TO BE OBSERVED WHEN USING THE INTERFACE COMMAND SET

- All commands listed in the table are assuming that a 6 phase Power Analyzer is used and thus PH_START = 1 and PH_END=6. If you are using a 3-Phase Power Analyzer Ph_START=1 and PH_END=3.
- In response to the command VOLT:MEAN?CRLF the 6 phase instrument sends Vmean of six phases, and the 3 phase instrument sends Vmean of three phases. Every value consists of 8 ASCII characters, e.g. -999.58m. The string for a 3 phase instrument could look like this:

  VOLT:MEAN?CRLF $\rightarrow$ 999.58m 200.01m–1.0008 CRLF (26 ASCII characters).

  The string length is 24 characters followed by the terminators CR (carriage return) LF (line feed).

❋ One or several Control Commands marked with ❋ must be terminated with the control command DISplay:UPDATE. This assures that changes are transferred to the display processor to also update the display panel.

Suggestion: Send first all required control commands, such as CURRent:SC1 <R>, ACQuire:AUTO_V, ACQuire:INput, etc. one after the other; when done, send DISplay:UPDATE to transfer all changes to the display processor.

- The capital letters in the command list are mandatory. They can be sent upper case or lower case. The lower case letters in the command set can be added if desired.

- <R> = decimal number, e.g. 2000.5. It follows the command with one space.

- <N> = integer number, e.g. 32000. It follows the command with one space.

- Every command must be terminated with CR/LF (carriage return / line feed).

- Query commands are terminated by a question mark and CR/LF. The Power Analyzer returns measurement values.

  Example: volt:rms?CRLF returns rms voltages of all phases.
  curr:sc1?CRLF returns scaling factor phase 1.

  The question mark follows the command without space

- Set commands. Examples of set commands:

  CURR:SC3 <R>; CURR:SC3 2000.5CRLF, sets current scaling factor phase 3 to 2000.5. There is one space between SC3 and 2000.5.

  FORM:PH_END <N> FORM:PH_END 3CRLF, sets phase end to 3.
  If you are using a 6-phase Power Analyzer the query volt:rms? returns 3 voltages phase 1, 2, and 3.

- DISP:BATCH command is used to configure up to 4 pages (32 lines) of the display in a single batch. The following example shows how to reconfigure the first 6 lines on page 1.

  DISP:BATCH A02A03A04A36A06A83CRLF. This command reconfigures the first 6 lines of the display page 1. The batch values of all displayable quantities you find in tables 3.1 and A83 you find in table 3.2

A02	rectified mean current	on display line 1
A03	rms voltage,	on display line 2
A04	DC-voltage,	on display line 3
A36	fundamental voltage V01,	on display line 4
A06	active power,	on display line 5
A83	ratio 1 = Pact2 / Pact1 in display column 1, line 6 ratio 2 = (Pact1 + Pact2) / Pact3 in display column 2, line 6 ratio 3 = (Pact3 + Pact4) / (Pact1 + Pact2) in display column 3, line 6	

Maximum 32 batch values Axy can be sent. Using Table 3.2 sums, ratios, motor values, transformer values, analog inputs, and frequency inputs can be displayed.

- Composite commands Table 5.1 using a 3 Phase Power Analyzer.

COMP:CMP1?	returns:3 Vrms, 3 Arms, and 3xW, terminated with CRLF. The data string is:Vrms1, Vrms2, Vrms3, Arms1, Arms2, Arms3, W1, W2, W3, CRLF. Where Vrms1 = voltage phase 1, etc. The string length is 9 x 8 + 2 = 74 ascii characters.
COMP:CMP2?	returns: 3 Vrms, 3 Arms, 3 W, 3 VA, 3 PF, 3 Wh, 3 elapsed time. Data string length = 21 · 8 + 2 = 170 ascii characters.
COMP:CMP3?	3 V1, 3 A1, 3 W1, 3VA1, 3 PF1, 3 Z1, 3 Phi1. V1, … Phi1 are FFT-values of the fundamental frequency.
COMP:DSP1?	returns the displayed values of display line 1, 2, 3, and 4 of page 1. For a 3-phase instrument there will be 12 quantities. For a 6-phase instrument there will be 24 quantities.
COMP:SUMS?	returns SUM1, SUM2, SUM3, SUM4, SUM5, and SUM6 defined in table 3.2. Note: SUM4, SUM5, and SUM6 are zero when a 3-phase power Analyzer is used.
COMP:RATIO?	returns 6 ratios, These ratios define efficiencies. Use the defined ratios in table 3.2 and hook up the Power Analyzer accordingly. *Example: ratio 1 = Pact2 / Pact1. It requires connecting the system input to phase 1 and the system output to phase 2.*
COMP:MOTOR1?	returns 6 motor1 values from connection to phase 1, 2, 3.
COMP:MOTOR2?	Returns 6 motor2 values from connection to phase 4, 5, 6.
COMP:MOT1_Loss?	returns 6 motor values when motor1 is idling. It stores motor loss and is then used in command COMP:MOTOR1? To calculate motor output power on the drive shaft.
COMP:MOT2_Loss?	returns 6 motor values when motor2 is idling. It stores motor loss and is then used in command COMP:MOTOR2? To calculate motor output power on the drive shaft
COMP:TRAFO?	returns 6 transformer values from phase 1 and phase 2 at idle and short circuit.
COMP:ANIN?	returns the values of 6 analog inputs. 4x ±5V and 2x ±10V inputs.
COMP:VLTL?	returns 6 line to line voltages according to definition at end of Table 3.2.

Computer Interface Command Set

Throughout the command set tables it is assumed a 6 phase Power Analyzer is used. If you are using a 3 phase instrument “6x” must be replaced by “3x”.
The default for ph_start=1 (Table 5.7). The default of ph_end is equal the number of phases installed in your instrument.
Example: You are using a 6 phase Power Analyzer. After start-up you send the command: comp:cmp1?.
In return you receive 6x Vrms, 6x Arms, and 6x W; measurement values from phase 1, 2, … , 6. If you send the command “form: ph_start 4” the Power Analyzer will return to the command “comp:cmp1?” 3x Vrms, 3x Arms, and 3x W; measurement values from phase 4, 5, and 6.

Composite commands, read several quantities with one command.

Table 5.1 composite commands

Command	Output for a 6 phase instrument with PH_START=1, PH_END=6
COMPose:CMP1?	6x Vrms, 6x Arms, 6x Watt, phase 1 value first
COMPose:CMP2?	6x Vrms, 6x Arms, 6x W, 6x VA, 6x PF, 6x Wh, 6x time
COMPose:CMP3?	6x Fundamental V1, A1, W1, VA1, PF1, Z1, Phi1
COMPose:CMP4?	6x Wh, VAh, Varh, Ah, time since RESET
COMPose:DSP1?	6x Display value line 1, 6x line 2, 6x line 3, 6x line 4 of page 1
COMPose:DSP2?	6x Display value line 5, 6x line 6, 6x line 7, 6x line 8 of page 1
COMPose:SUMS?	1x SUM1, 1x SUM2, 1x SUM3, 1x SUM4, 1x SUM5, 1x SUM6 (table 3.2)
COMPose:RATIO?	1x Ratio1, 1x Ratio2, 1x Ratio3, 1x Ratio4, 1x Ratio5, 1x Ratio 6
COMPose:MOTOR1?	1x Winput, 1x Woutput, 1x Torque, 1x Slip, 1x Speed, 1x Efficiency
COMPose:MOTOR2?	1x Winput, 1x Woutput, 1x Torque, 1x Slip, 1x Speed, 1x Efficiency
COMPose:MOT1_Loss?	Stores motor1 power consumed without load. Output 6 motor values.
COMPose:MOT2_Loss?	Stores motor2 power consumed without load. Output 6 motor values.
COMPose:TRAFO?	1x Vrect x1.11, Wcorrected, Qfactor, Reqiv, Xeqivalent, n2/n1
COMPose:ANIN?	4x Analog input ±5V, 2x Analog input ±10V
COMPose:VLTL?	6x voltage line to line (Table 3.2)

Reading voltages, reading and writing voltage scale factors

Table 5.2 Voltages Reading Commands

VOLTage:RMS?	6x Vrms (root mean square), phase 1 value first.
VOLTage:FUND?	6x fundamental of voltage (V1)
VOLTage:RECT?	6x Vrect (rectified mean of voltage)
VOLTage:MEAN?	6x Vmean (is valied also when AC coupling is used)
VOLTage:MIN?	6x minimum voltage
VOLTage:MAX?	6x maximum voltage
VOLTage:PEAK?	6x peak to peak voltage
VOLTage:FFTL1?	Harmonics L1: V1, V2, …, V40. Can be changed by altering FFT_START, FFT_END (max. 88)
VOLTage:FFTL2?	Harmonics L2: V1, V2, …, V40. Can be changed by altering FFT_START, FFT_END (max. 88)
VOLTage:FFTL3?	Harmonics L3: V1, V2, …, V40. Can be changed by altering FFT_START, FFT_END (max. 88)
VOLTage:FFTL4?	Harmonics L4: V1, V2, …, V40. Can be changed by altering FFT_START, FFT_END (max. 88)
VOLTage:FFTL5?	Harmonics L5: V1, V2, …, V40. Can be changed by altering FFT_START, FFT_END (max. 88)
VOLTage:FFTL6?	Harmonics L6: V1, V2, …, V40. Can be changed by altering FFT_START, FFT_END (max. 88)
VOLTage:THD1?	6x THD1 = $(Vrms^2 – V1^2)^{1/2}/Vrms$. Use it for frequency inverter.
VOLTage:THD2?	6x THD2 = $\Sigma(Vn^2)^{1/2}/Vrms$, n = 2 -40.
VOLTage:CREST?	6x Voltage Crest Factor
VOLTage:FORM?	6x Voltage Form Factor
VOLTage:CURVEL1?	512 samples of wave L1. Each sample 3 ascii numbers centered around 500 ±255.
VOLTage:CURVEL2?	512 samples of wave L2. Each sample 3 ascii numbers centered around 500 ±255.
VOLTage:CURVEL3?	512 samples of wave L3. Each sample 3 ascii numbers centered around 500 ±255.
VOLTage:CURVEL4?	512 samples of wave L4. Each sample 3 ascii numbers centered around 500 ±255.
VOLTage:CURVEL5?	512 samples of wave L5. Each sample 3 ascii numbers centered around 500 ±255.
VOLTage:CURVEL6?	512 samples of wave L6. Each sample 3 ascii numbers centered around 500 ±255.
VOLTage:SC1 <R> ❋	Read Voltage Scaling Factor L1: VOLT:SC1? Write voltage scaling factor L1: VOLT:SC1 20.15 or 2.015e1
VOLTage:SC2 <R> ❋	Read Voltage Scaling Factor L2: VOLT:SC2? Write voltage scaling factor L2: VOLT:SC2 20.15 or 2.015e1
VOLTage:SC3 <R> ❋	Read Voltage Scaling Factor L3: VOLT:SC3? Write voltage scaling factor L3: VOLT:SC3 20.15 or 2.015e1
VOLTage:SC4 <R> ❋	Read Voltage Scaling Factor L4: VOLT:SC4? Write voltage scaling factor L4: VOLT:SC4 20.15 or 2.015e1
VOLTage:SC5 <R> ❋	Read Voltage Scaling Factor L5: VOLT:SC5? Write voltage scaling factor L5: VOLT:SC5 20.15 or 2.015e1
VOLTage:SC6 <R> ❋	Read Voltage Scaling Factor L6: VOLT:SC6? Write voltage scaling factor L6: VOLT:SC6 20.15 or 2.015e1

Reading currents, reading and writing current scale factor

Table 5.3 Current Reading Commands

CURRent:RMS?	6x Arms (root mean square), phase 1 value first.
CURRent:FUND?	6x fundamental of current (A1)
CURRent:RECT?	6x Arect (rectified mean of current)
CURRent:MEAN?	6x Amean (is valied also when AC coupling is used).
CURRent:MAX?	6x maximum current
CURRent:FFTL1?	Harmonics L1: A1, A2, …, A40. Can be changed by altering FFT_START, FFT_END (max. 88).
CURRent:FFTL2?	Harmonics L2: A1, A2, …, A40. Can be changed by altering FFT_START, FFT_END (max. 88).
CURRent:FFTL3?	Harmonics L3: A1, A2, …, A40. Can be changed by altering FFT_START, FFT_END (max. 88).
CURRent:FFTL4?	Harmonics L4: A1, A2, …, A40. Can be changed by altering FFT_START, FFT_END (max. 88).
CURRent:FFTL5?	Harmonics L5: A1, A2, …, A40. Can be changed by altering FFT_START, FFT_END (max. 88).
CURRent:FFTL6?	Harmonics L6: A1, A2, …, A40. Can be changed by altering FFT_START, FFT_END (max. 88).
CURRent:THD1?	6x THD1 = $(Arms^2 – A1^2)^{1/2}$/Arms. Use if for frequency inverter.
CURRent:THD2?	6x THD2 = $\Sigma(An^2)^{1/2}$/Arms, n = 2, 3, …, 40.
CURRent:CREST?	6x current crest factor
CURRent:FORM?	6x current form factor
CURRent:CURVEL1?	512 samples of wave L1. Each sample 3 ascii numbers centered around 500 ±255.
CURRent:CURVEL2?	512 samples of wave L2. Each sample 3 ascii numbers centered around 500 ±255.
CURRent:CURVEL3?	512 samples of wave L3. Each sample 3 ascii numbers centered around 500 ±255.
CURRent:CURVEL4?	512 samples of wave L4. Each sample 3 ascii numbers centered around 500 ±255.
CURRent:CURVEL5?	512 samples of wave L5. Each sample 3 ascii numbers centered around 500 ±255.
CURRent:CURVEL6?	512 samples of wave L6. Each sample 3 ascii numbers centered around 500 ±255.
CURRent:SC1 <R> ❋	Read current scaling factor L1: CURR:SC1? Write current scaling factor L1: CURR:SC1 2000.0 or 2.0e3
CURRent:SC2 <R> ❋	Read current scaling factor L2: CURR:SC2? Write current scaling factor L2: CURR:SC2 2000.0 or 2.0e3
CURRent:SC3 <R> ❋	Read current scaling factor L3: CURR:SC3? Write current scaling factor L3: CURR:SC3 2000.0 or 2.0e3
CURRent:SC4 <R> ❋	Read current scaling factor L4: CURR:SC4? Write current scaling factor L4: CURR:SC4 2000.0 or 2.0e3
CURRent:SC5 <R> ❋	Read current scaling factor L5: CURR:SC5? Write current scaling factor L5: CURR:SC5 2000.0 or 2.0e3
CURRent:SC6 <R> ❋	Read current scaling factor L6: CURR:SC6? Write current scaling factor L6: CURR:SC6 2000.0 or 2.0e3

Reading power, apparent power, and reactive power

Table 5.4 Power Reading Commands

POWer:ACTive?	6x W (active power)
POWer:APParent?	6x VA (apparent power)
POWer:REActive?	6x Var (reactive power)
POWer:FFTL1?	Power Harmonics L1: W1, W2, …, W21. Can be changed by altering FFT_START, FFT_END (max. 21)
POWer:FFTL2?	Power Harmonics L2: W1, W2, …, W21. Can be changed by altering FFT_START, FFT_END (max. 21)
POWer:FFTL3?	Power Harmonics L3: W1, W2, …, W21. Can be changed by altering FFT_START, FFT_END (max. 21)
POWer:FFTL4?	Power Harmonics L4: W1, W2, …, W21. Can be changed by altering FFT_START, FFT_END (max. 21)
POWer:FFTL5?	Power Harmonics L5: W1, W2, …, W21. Can be changed by altering FFT_START, FFT_END (max. 21)
POWer:FFTL6?	Power Harmonics L6: W1, W2, …, W21. Can be changed by altering FFT_START, FFT_END (max. 21)
POWer:FACTor?	6x Power factor W/VA
POWer:ACT1?	6x fundamental Power W1 (Harmonic 1)
POWer:APP1?	6x fundamental apparent power VA1 (Harmonic 1)
POWer:REA1?	6x fundamental reactive power Var1 (Harmonic 1)
POWer:FAC1?	6x power factor of fundamental (Harmonic 1)
POWer:DIST?	6x Apparent power of distortion = $V1(A2^2 + \ldots + A40^2)^{1/2}$

Reading energy, charge, and time

Table 5.5 Energy Reading Commands

ENergy:ACTive?	6x active energy Wh
ENergy:APParent?	6x apparent energy VAh
ENergy:REActive?	6x reactive energy Varh
ENergy:CHArge?	6x charge in Ah = ∫Arect x dt
ENergy:TIME?	6x elapsed time since RESET in hours
ENergy:RESET	Resets all energy values including Ah and Time

Reading frequency, impedance, and phase angle.

Table 5.6 Frequency, Impeadance, Phase Angle Reading Commands

FREQency?	6x frequency of current or voltage (fundamental)
IMPedance:MAG?	6x magnitude of impedance = V1/A1 (fundamental)
IMPedance:ANGle?	6x phase angle of fundamental impedance
IMPedance:FFT_ANGL1?	Phase angle L1: phi1, phi2, …, phi21
IMPedance:FFT_ANGL2?	Phase angle L2: phi1, phi2, …, phi21
IMPedance:FFT_ANGL3?	Phase angle L3: phi1, phi2, …, phi21
IMPedance:FFT_ANGL4?	Phase angle L4: phi1, phi2, …, phi21
IMPedance:FFT_ANGL5?	Phase angle L5: phi1, phi2, …, phi21
IMPedance:FFT_ANGL6?	Phase angle L6: phi1, phi2, …, phi21

Reading and writing range of harmonics, number phases for output, and cycle for Logging

Table 5.7 Format Reading Commands

FORMat:FFT_START <N>	Read FFT_START 1-88. FORM:FFT_START? Write FFT_START 1-88. FORM:FFT_START 18. Set harmonic to 18.
FORMat:FFT_END <N>	Read FFT_END 1-88. FORM:FFT_END? Write FFT_END 1-88. FORM:FFT_END 50. Set harmonic end to 50.
FORMat:PH_START <N>	Read PH_START 1-6. FORM:PH_START? Write PH_START 1-6. FORM:PH_START 5. Set phase start to 5.
FORMat:PH_END <N>	Read PH_END 1-6. FORM:PH_END? Write PH_END 1-6. FORM:PH_END 3. Set phase end to 3.
FORMat:CYCLE <N>	Read CYCLE (for logging). FORM:CYCLE?, integer max. 32000. Write CYCLE (for logging). FORM:CYCLE 32000. Set cycle to max.

Read and write display, RS232 Baud Rate, IEEE-488 address

Table 5.8 Display, Interface, Analog Scaling Commands

DISplay:PAGE <N> ❋	Read active display page 1-4. DISP:PAGE? Write display page 1-4. DISP:PAGE 4. Display shows values of page 4.
DISplay:BATCH ❋	Example to change the display values of page 1, line 1, 2, 3, 4 DISP:BATCH A00A03A06A14. Arms, Vrms, Pact, Wh. (Table 3.1 and 3.2)
DISplay:AN_SC1	Read analog1 scaling factor: DIS:AN_SC1? Write analog1 scaling factor: DIS:AN_SC1 2.0
DISplay:AN_SC2	Read analog2 scaling factor: DIS:AN_SC2? Write analog2 scaling factor: DIS:AN_SC2 10.0
DISplay:AN_SC3	Read analog3 scaling factor: DIS:AN_SC3? Write analog3 scaling factor: DIS:AN_SC3 5.1
DISplay:AN_SC4	Read analog4 scaling factor: DIS:AN_SC4? Write analog4 scaling factor: DIS:AN_SC4 201.0
DISplay:AN_SC5	Read analog5 scaling factor: DIS:AN_SC5? Write analog5 scaling factor: DIS:AN_SC5 0.85
DISplay:AN_SC6	Read analog6 scaling factor: DIS:AN_SC6? Write analog6 scaling factor: DIS:AN_SC6 1.0
DISplay:RPM_SC1	Read rpm1 scaling factor: DIS:RPM_SC1? Write rpm1 scaling factor: DIS:RPM_SC1 2.0
DISplay:RPM_SC2	Read rpm2 scaling factor: DIS:RPM_SC2? Write rpm2 scaling factor: DIS:RPM_SC2 8.0
RS232 <N> ❋	Read BAUD-ID. RS232? → Output: 4, 0, 0. First Integer = Baud-ID Write BAUD-ID. RS232 5. Baud-ID = 0,1, … 7=9.6/19.2/38.4/56.6/115.2/230.4/460.8/921.6k Baud
GPIB:ADDRess <N> ❋	Read GPIB ADDRESS: GPIBL:ADDR? address 1- 31. Write GPIB ADDRESS: GPIB:ADDR 20, wr address 20.
DISplay:UPDATE ❋	Write update command to send all changes to the display

Read and write common control commands.

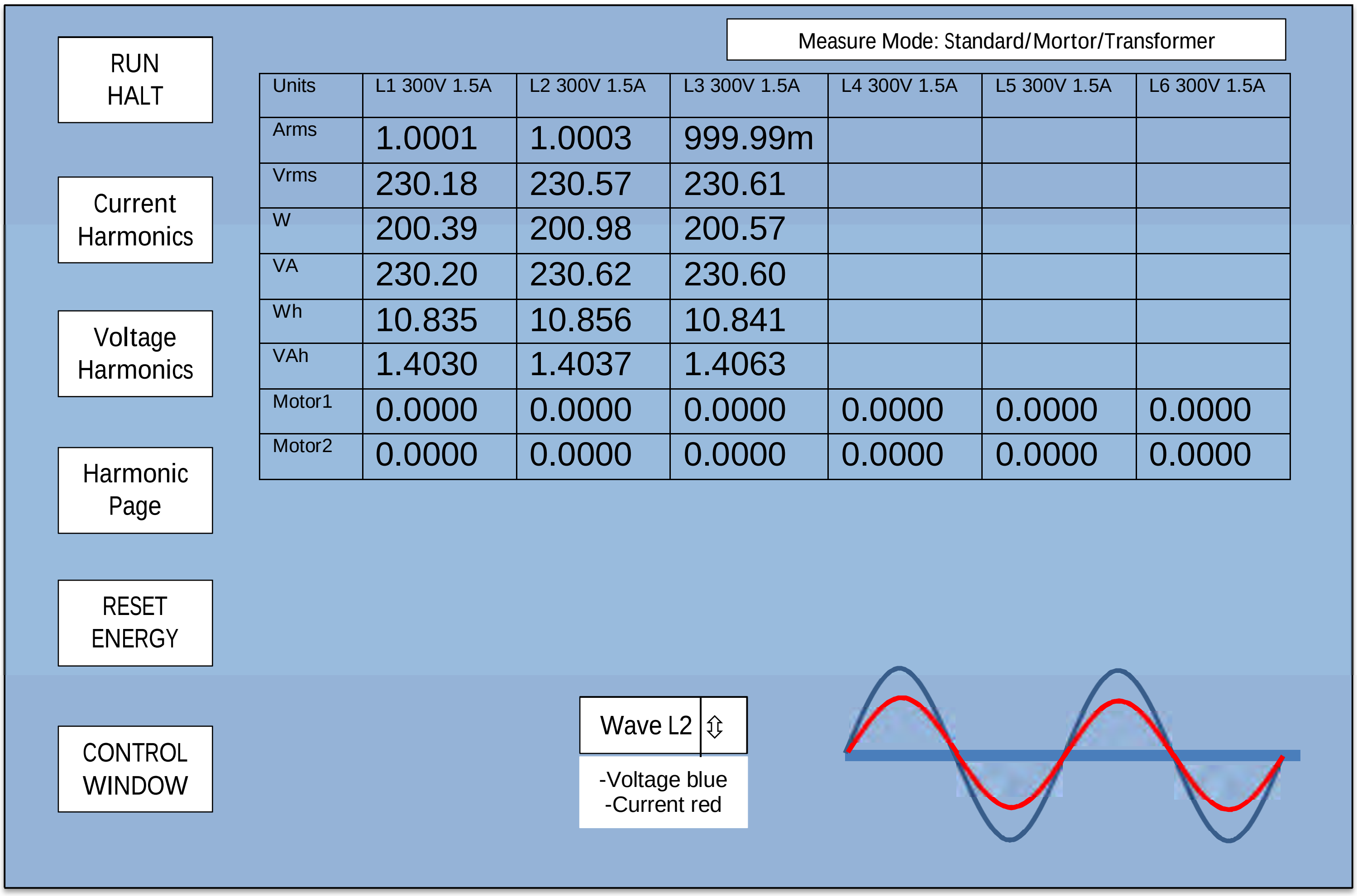
Table 5.9 Control Commands

VERsion?	Read type of instrument, Software, number phase
ACQuire:AUTO_V ✱	Read V-auto ranging: ACQ:AUTO_V? 1/0=auto ranging on/off Set auto ranging on: ACQ:AUTO_V 1. Sets all phases to auto.
ACQuire:AUTO_A ✱	Read A-auto ranging: ACQ:AUTO_A? 1/0=auto ranging on/off Set A-auto ranging on: ACQ:AUTO_V 1. Sets all phases to auto.
ACQuire:RANGE_V ✱	Read V-range: ACQ:RANGE_V? 0,1,2,3,4,5,6,7=0.3,1,3,10,30,100, 300, 1000V Set 300V range: ACQ:RANGE_V 6. Sets all phases to 300V range.
ACQuire:RANGE_A ✱	Read A-range: ACQ:RANGE_A? Current input 1A/ 5A/ 30A = 0,1,2,3,4,5,6 / 0,1,2,3,4,5,6 / 0,1,2,3,4. Set 5mA/ 50mA/ 3A range: ACQ:RANGE_A 1.
ACQuire:Input ✱	Read current input id: ACQ:IN? 1A=3, 5A=0, 30A=1, Shunt=2. Set current input 30A: ACQ:IN 1.
ACQuire:SYNChro ✱	Read synchronization: ACQ:SYNC? 0,1,2 = current / voltage / external Set synchronization: ACQ:SYNC 0. 0 = current synchronization.
ACQuire:APERture ✱	Read averaging time: ACQ:APER?. 0, 1, 2, 3, 4=0.5s, 1s, 2s, 8s, 32s Set averaging time: ACQ:APER 1. 5 = Fast (100ms)
ACQuire:QU_V	Read V-under, -ok, -over: ACQ:QU_V? 0, 1, 2=ok, over-, under range.
ACQuire:QU_A	Read A-under, -ok, -over: ACQ:QU_A? = 0, 1, 2=ok, over-, under range.
ACQuire:DC_AC ✱	Read coupling of input amplifiers: ACQ:DC_AC? 0=DC, 1=AC Set coupling of input amplifiers: ACQ:DC_AC 1. Set AC coupling.
ACQuire:MODE ✱	Read measure mode: ACQ:MODE? 0=standard, 1=Logging Set measure mode: ACQ:MODE 0. Set standard.
ACQuire:TRANS_ID ✱	Read duration transient: ACQ:TRANS_ID? 0, 1, 2, 3, 4, 5 , 6=duration in sec. 0.25, 0.5, 1, 2, 4, 8, 16 Set duration: ACQ:TRANS_ID 2. 2=1 sec.
ACQuire:AVG_FFT ✱	Read fft-averaging: ACQ:AVG_FFT? 0,1,2,3,4 = Every fft-point is an average of 4, 16, 64, 256, 1024 samples. Set fft-averaging: ACQ:AVG_FFT 1.
ACQuire:SUPRESS ✱	Read suppress: ACQ:SUPRESS? 0=suppress off, 1=on Set suppress: ACQ:SUPRESS 1. Suppress on.
ACQuire:Hold ✱ ✱	Set display run: ACQ:Hold 0. Set display hold: ACQ:Hold 1.
ACQuire:GO	ACQ:GO starts measurement if in Logging, transient or power-speed. Has no effect in standard measure mode.
ACQuire:HALT	ACQ:HALT stops measurement if in Logging, transient or power speed. Has no effect in standard measure mode.
ACQuire:SETTING ✱	ACQ:SETTING? Output is previously loaded setting number 0,1,2, .. ACQ:SETTING 12 Loads setting number 12 if present in memory.
ACQuire:NR_POLE1	Read number motor poles, motor1 ACQ:NR_POLE1? 2, 4, 6, 8, 10, 12 … Set number of motor1 poles to 12: ACQ:NR_POLE1 12.
ACQuire:NR_POLE2	Read number motor2 poles, motor2 ACQ:NR_POLE2? 2, 4, 6, 8, 10, 12 … Set number of motor2 poles to 12: ACQ:NR_POLE2 6.

6. Computer Operating Software

The Power Analyzer Computer Operating Software consists basically of 2 main Windows: the display window and the control window. The display window displays the measured values, and the actual ranges of current and voltage. A reserved field is for displaying voltage- and current wave forms. The control window lets you select the current inputs, the synchronization, the ranges for current and voltages, the averaging time, the measure mode, the values to be displayed, and scaling factors of the current, voltage, and analog inputs.

- **Display Window**



Units	L1 300V 1.5A	L2 300V 1.5A	L3 300V 1.5A	L4 300V 1.5A	L5 300V 1.5A	L6 300V 1.5A
Arms	1.0001	1.0003	999.99m			
Vrms	230.18	230.57	230.61			
W	200.39	200.98	200.57			
VA	230.20	230.62	230.60			
Wh	10.835	10.856	10.841			
VAh	1.4030	1.4037	1.4063			
Motor1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Motor2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

- **CONTROL WINDOW**

CONTROL WINDOW

Current Input	Voltage Range	Measure Mode	Scaling		
			Current		Voltage
40A □	1000V □	Standard ■	1.0000	L1	1.0000
5A ■	300V ■	Logging □	✓	L2	✓
1A □	100V □	Transient □	✓	L3	✓
Shunt □	30V □	Power-Speed □	✓	L4	✓
	10V □		✓	L5	✓
Current Range	3V □	Com1 RS232	✓	L6	✓
	1V □	Baud ⇳115.2k			
15A □	0.3V □	IEEE 488	Scaling		
5A □	AUTO □	ADR ⇳5	Analog 1/2		Speed 1/2
500mA □			1.0000	1	1.0000
150mA □	Averaging Coupling	Store Data	✓	2	✓
50mA □					
15mA □	FAST ■	Yes | No			
AUTO ■	0.5s □	File name			
	1s □	Interval ⇳10	Configure Display Table		
Synchronization	2s □	seconds			
	8s □		Standard Measure Mode Only		
Current □	32s □	Motor	Table Line	⇳1	Select
Voltage □	AC □	nr_pole1 ⇳4			
External □	AC+DC ■	nr_pole2 ⇳6			

- Pop up of Value Selection Table 2800
- Click on desired quantity for line 1
- Increment to next line, → select
- Pop up of Value Selection Table
- Click on desired quantity for line 2

etc. [example: A00A03A06….A07]
All 8 lines must be configured.
send dis:batch_A00A03A06…..A07
→ configures 2800 display

RUN
→ send comp:dsp1? → read values display line 1-4
→ send comp:dsp2? → read values display line 5-8

Logging: The display table is predetermined.
First to eight line: frequency, Arms, Vrms, W, PF, VA, Wh, and VAh.

7. ANALOG INPUT AND -OUTPUT

The rear panel DB37 connector Figure 7.1 provides all signals for processing inputs to- and processing outputs from the Power Analyzer.

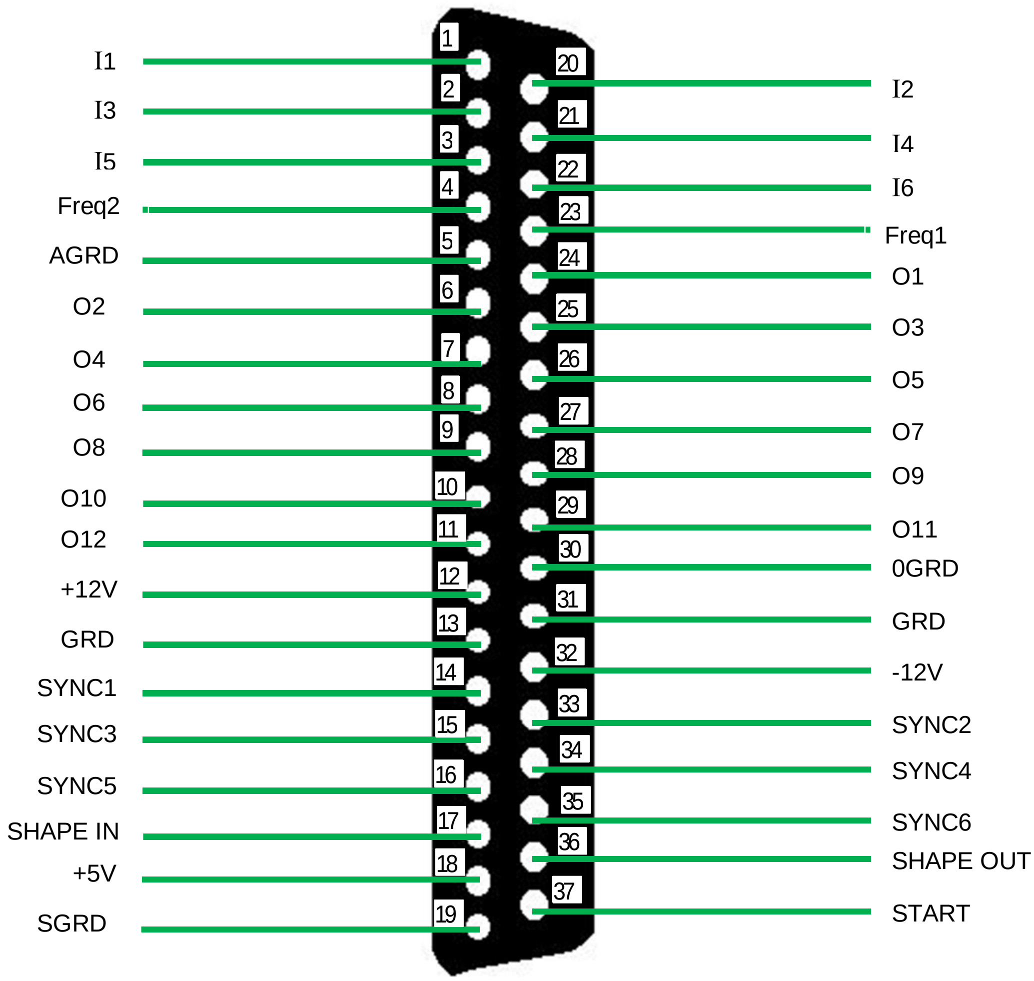


Figure 7.1: Process Input-Output Connector DB37

Symbol	Description
I1-I4	Analog inputs -5V to +5V, if not used short to AGRD
I5-I6	Analog inputs -10V to +10V, if not used short to AGRD
Freq1	TTL frequency range 5Hz to 150kHz
Freq2	TTL frequency range 20Hz to 150kHz
AGRD	Ground for input signals (analog and TTL)
01-012	Output of displayed values, ±5V max
+12V/GRD/-12V	Supply for external current sensor unit (300mA)
SYNC1-SYNC6	Synchronization inputs or outputs for external synchronization
SHAPE IN	0-80Vac input to form a TTL signal
SHAPE OUT	Sharper TTL output, can be applied to Sync1-Sync6
SGRD	Ground for Sync1-Sync6 inputs.
START	Provides hardware start by connecting to 5V/pin18. (Logging/Transient/Power-Speed)

● Analog Input And Output Specification

Analog input 1-4, span:	-5V to +5V, Ri = 100kΩ, Typical max error 0.2 %
	If not used short inputs to AGRD
Analog input 5,6, span:	-10V to +10V, Ri = 100kΩ, Typical max error 0.2 %
	If not used short inputs to AGRD
Frequency input 1,2:	20Hz – 150kHz, Typical max error 0.2 %
Analog output 1-12:	-5V to +5V, Rout = 1kΩ, Typical max error 0.2 %
Update interval:	0.5 sec
Output quantities:	Arms, Vrms, W, VA, Var, PF1, -5V to +5V. Frequency, Wh as relative output: 0.3125V – 5V. When output reaches 5V it drops to 5V/16 and so forth (increasing values). When output falls below 0.3125V it increases to 0.3125 x 16 (decreasing values).

● Programming The Analog Outputs

In standard measure mode all analog inputs, Freq1, and Freq2 are measured in 500ms time intervals. All analog outputs are set according to the criteria described below.
In power-speed measure mode freq1 is measured in 20ms time intervals. At Start analog output1 is set to +5V and can be used to start the system under test (power-speed only).
In logging- and transient measure mode the analog option is not used.

In standard measure mode the displayed quantities on display page 1 are applied to the analog outputs. The output configuration depends on the number of phases installed in the Power Analyzer.

Below examples of output configurations are given:

Single phase:	Display lines 1 to 8 = Arms, Vrms, W, VA, Var, PF1, frequency, Wh. Analog output 1, 2, 3, 4, 5, 6, 7, 8 are proportional to Arms, Vrms, W, VA, Var, PF1, freq, Wh. Analog outputs 9, 10, 11, 12 are zero.	
Two phase:	Display lines 1 to 6 are Arms, Vrms, W, PF1, VA, Wh.	
	Analog output 1, 2 =	Arms of phase 1 and phase 2
	Analog output 3, 4 =	Vrms of phase 1 and phase 2
	Analog output 5, 6 =	W of phase 1 and phase 2
	Analog output 7, 8 =	PF1 of phase 1 and phase 2
	Analog output 9, 10 =	VA of phase 1 and phase 2
	Analog output 11, 12 =	Wh of phase 1 and phase 2
Three phase:	Display lines 1 to 4 =	W, VA, Arms, PF1
	Analog output 1, 2, 3 =	W phase 1, 2, 3
	Analog output 4, 5, 6 =	VA phase 1, 2, 3
	Analog output 7, 8, 9 =	Arms phase 1, 2, 3
	Analog output 10, 11, 12 =	PF1 phase 1, 2, 3
Four phase:	Display lines 1 to 3 =	Arms, W, VA
	Analog output 1, 2, 3, 4 =	Arms phase 1, 2, 3, 4
	Analog output 5, 6, 7, 8 =	W phase 1, 2, 3, 4
	Analog Output 9, 10, 11, 12 =	VA phase 1, 2, 3, 4
Five phase:	Display lines 1 to 3 =	Arms, W, VA
	Analog output 1, 2, 3, 4, 5 =	Arms phase 1, 2, 3, 4, 5
	Analog output 6, 7, 8, 9, 10 =	W phase 1, 2, 3, 4, 5
	Analog output 11, 12	VA phase 1 and phase 2
Six phase:	Display lines 1 and 2 =	Arms, W
	Analog output 1, 2, 3, 4, 5, 6 =	Arms phase 1, 2, 3, 4, 5, 6
	Analog output 7, 8, 9, 10, 11, 12 =	W phase 1, 2, 3, 4, 5, 6

- **USING INPUTS FOR MOTOR TESTING (SEE ALSO 4.1 MOTOR TESTING)**
  Using a 6 phase Power Analyzer two motors can be tested simultaneously. Motor1 is connected to phase 1, 2, and 3. Motor2 is connected to phase 4, 5, and 6. Speed of motor1 is measured via TTL FREQ1 input, and Speed of motor2 is measured via TTL FREQ2 input. Both inputs exhibit excellent accuracy over a wide frequency range 20Hz to 150kHz. A rotating disc with 180 divisions at 150kHz will display 50000 rpm (rotations per minute). FREQ1 and FREQ2 can be scaled via interface commands to accommodate different speed sensor. External torque transducers can be connected to one of the six analog inputs. All inputs can be scaled in the SETUP window or using the interface to display actual torque.

  Power-Speed measurements are limited to phase 1, 2, and 3 and Freq1 speed input.

8. CALIBRATION

A calibration cycle of two years is appropriate. If occasional overloads occur (greater two times maximum value) we recommend one year calibration cycle.

8.1 EQUIPMENT NEEDED

Voltage: 0.3V, 1V, 3V, 10V, 30V, 100V, 300V, 1000V; 60Hz

Current: 1.5mA, 5mA, 15mA, 50mA, 150mA, 500mA, 1.5A;
1A, 3A, 10A, 20A; 60Hz

8.2. CALIBRATION PROCEDURE

- **Set all voltage- and current scaling factors to 1.0000.**
- Select Standard Measure Mode, select 1 second averaging
- Touch SETUP. In the pop-up window touch Calibrate 2800. Enter your calibration code 7123.
- Touch one of the buttons Voltage Calibration or Current Calibration.
  You will exit to the Standard Measure Mode. The bottom line of the display, will display the button TAKE VOLTAGE READING or TAKE CURRENT READING depending on what you selected in the setup menu.
  Now proceed with section 8.2.1 Voltage Calibration at 60Hz or section 8.2.2 Current calibration at 60Hz

8.2.1 VOLTAGE CALIBRATION AT 60HZ

You must select Sync V. Touch button TAKE VOLTAGE READING when values have stabilized. Apply voltage to all phases simultaneously.

Select 0.3V	range, apply 0.3V,	wait	→ touch TAKE VOLTAGE READING
Select 1V	range, apply 1V,	wait	→ touch TAKE VOLTAGE READING
Select 3V	range, apply 3V,	wait	→ touch TAKE VOLTAGE READING
Select 10V	range, apply 10V,	wait	→ touch TAKE VOLTAGE READING
Select 30V	range, apply 30V,	wait	→ touch TAKE VOLTAGE READING
Select 100V	range, apply 100V,	wait	→ touch TAKE VOLTAGE READING
Select 300V	range, apply 300V,	wait	→ touch TAKE VOLTAGE READING
Select 1000V	range, apply 1000V,	wait	→ touch TAKE VOLTAGE READING

If only voltage calibration was needed continue with Section 8.2.3 “Storing the Calibration Constants”.

8.2.2 CURRENT CALIBRATION AT 60HZ, SHUNT INPUT CALIBRATION

You must select Sync A.

a.) Select Current Input **IN 5A**.

Apply current to all current inputs in series.

Select 15mA range, apply 15mA, wait → touch TAKE CURRENT READING

Select 50mA range, apply 50mA, wait → touch TAKE CURRENT READING

Select 150mA range, apply 150mA, wait → touch TAKE CURRENT READING

Select 500mA range, apply 500mA, wait → touch TAKE CURRENT READING

Select 1.5A range, apply 1.5A, wait → touch TAKE CURRENT READING

b.) Select current input **IN 1A**, use 1A input 3 pole connector.

Select 150mA range, apply 150mA wait → touch TAKE CURRENT READING

Select 500mA range, apply 500mA wait → touch TAKE CURRENT READING

Select 1.5A range, apply 1.0A, wait → touch TAKE CURRENT READING

c.) Select current input **IN 30A**, remove 1A input 3 pole connector and insert short circuit cover.

Select 1A range, apply 1A, wait → touch TAKE CURRENT READING

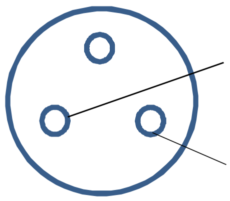
Select 3A range, apply 3A, wait → touch TAKE CURRENT READING

Select 10A range, apply 10A wait → touch TAKE CURRENT READING

Select 30A range, apply 20A, wait → touch TAKE CURRENT READING

Select 100A range, apply 20A, wait → touch TAKE CURRENT READING d.) Shunt input calibration at 60Hz

Remove the short circuit cover on the shunt input.



Select shunt input **SHUNT**.

Apply voltage to all shunt inputs in parallel.

Select 60mV	range, apply 60mV,	wait	→ touch TAKE CURRENT READING
Select 200mV	range, apply 180mV,	wait	→ touch TAKE CURRENT READING
Select 600mV	range, apply 600mV,	wait	→ touch TAKE CURRENT READING
Select 2V	range, apply 1.8V,	wait	→ touch TAKE CURRENT READING
Select 6V	range, apply 6V,	wait	→ touch TAKE CURRENT READING

8.2.3 Storing The Calibration Constants

At end of calibration the calibration constants are saved in nonvolatile memory.

- Enter the SETUP menu, touch Store Constants / Exit Calibration.
  This stores all calibration constants in nonvolatile memory.
  In case you do not want to store the calibration constants press the button Esc.
  The instrument returns to the Standard Measure Mode.

- **Wait at least 2 seconds. After calibration the Power Analyzer must be turned off and restarted for normal use.**

8.3. A Few Practical Hints

- It is acceptable to calibrate a single voltage range.
- It is acceptable to calibrate a single current range on the 30A input.
- It is acceptable to calibrate a single shunt input range.
- In case one of the ranges of the 5A input, or one of the ranges of the 1A input is out of tolerance all calibration steps of 8.2.2 a. and b. must be performed.
- **After calibration of a single range the Power Analyzer must be switched off and on again.**

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