Measurement, monitoring and power quality analysis in power systems
Fields of application

The APLUS is a comprehensive instrument for the universal measurement, monitoring and power quality analysis in power systems. The focus is on highest Swiss quality and maximum customer benefit. The device is suited for the application in power distribution, in strongly distorted industrial environments and in building automation. Nominal voltages up to 690 V can directly be connected.

The connection of the process environment may be performed by means of the communication interface, via digital I/Os or via analog outputs.

Possible applications in power systems

- Acquisition and control of the present system state
- Monitoring of the operational behaviour
- Analysis of the power quality
- Determining load profiles and energy demand values
- Finding the variations of the system load
- Measurement before and behind frequency converters
- Recording of operating procedures

Measurement of power quantities.

The APLUS can be adapted fast and easily to the measurement task by means of the CB-Manager software. The universal measurement system of the device may be used directly for any system, from single phase up to 4-wire unbalanced networks, without hardware modifications. Independent of measurement task and outer influences always the same high performance is achieved.

The measurement is performed in all four quadrants and can be adapted to the system to monitor in an optimal way. The measurement time as well as the expected system load can be parameterized.

<table>
<thead>
<tr>
<th>Measured quantity</th>
<th>Measurement uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage, current</td>
<td>± 0.1%</td>
</tr>
<tr>
<td>Power, imbalance</td>
<td>± 0.2%</td>
</tr>
<tr>
<td>Harmonics, THD, TDD</td>
<td>± 0.5%</td>
</tr>
<tr>
<td>Frequency</td>
<td>± 0.01 Hz</td>
</tr>
<tr>
<td>Load factor</td>
<td>± 0.1°</td>
</tr>
<tr>
<td>Energy</td>
<td>± 0.2% (Full scale)</td>
</tr>
<tr>
<td>- active energy</td>
<td>Class 0.5S (EN 62053-22)</td>
</tr>
<tr>
<td>- reactive energy</td>
<td>Class 2 (EN 62053-23)</td>
</tr>
</tbody>
</table>

Monitoring the operational behaviour.

To effectively protect operating resources it must be assured that multiple system quantities are within their allowed range. The logic module offers a comfortable facility to combine multiple limit values and to trigger further actions such as alarming, event registration or disturbance recording.

To monitor the operating time of specific loads up to three operating time counters are supported, which are controlled by means of limit values or digital operating feedbacks. One more operating time counter determines the time the APLUS itself has been switched on.

Possible applications of the logic module are:

- Function of protective relays (e.g. over-current, phase failure or imbalance)
- Changeover of the present operating mode, such as local/remote (day/night) operation
- Controlling the recording of alarms, events and acknowledgment procedures
- Monitoring of external devices: circuit states or self monitoring signals

- up to 12 limit values
- States of digital inputs
- Predefined states via bus
- Results of logic functions

Simulation Alarm reset

- Alarming via relay, digital outputs, alarm LED
- Entries into alarm or event list
- Triggering of disturbance recorder
Power quality analysis instead of failure analysis.

In the world of standards the quality of a grid is defined using statistical deviations from a desired standard behaviour. But what’s really needed when monitoring power quality is a statement if the used operating resources will work undisturbed under the real existing conditions.

The APLUS therefore does not work with statistics, but examines the real environment, to allow performing a corresponding immunity analysis. Almost all important aspects of power quality can be investigated and interpreted.

Variation of the system load
The absolute minimum/maximum values with timestamp are available for instantaneous and mean values. They indicate the bandwidth of the variations of the system parameters.

Using the extreme value data logger also short-term variations within an interval can be acquired. This way e.g. a load profile can be recorded, where along with the mean power also the highest and lowest short-term demand will be shown.

Additional load by harmonics
Harmonics originate from non-linear loads in the grid - a homemade pollution most of the time. They may induce an additional thermal stress to operational resources or wires and disturb the operation of sensitive loads.

The APLUS shows the harmonic contents of currents as Total Demand Distortion, briefly TDD. This value is scaled to the rated current resp. rated power. Only this way its influence on the connected equipment can be estimated correctly. In industrial grids the image of the harmonics often allows to determine quite good what types of loads are connected to the system.

Variation of the system load
The absolute minimum/maximum values with timestamp are available for instantaneous and mean values. They indicate the bandwidth of the variations of the system parameters.

Using the extreme value data logger also short-term variations within an interval can be acquired. This way e.g. a load profile can be recorded, where along with the mean power also the highest and lowest short-term demand will be shown.

Hint: The accuracy of the harmonic analysis depends strongly on the quality of the current and voltage transformers possibly used, because harmonics are normally heavily distorted. It’s valid: The higher the frequency of the harmonic, the higher its damping.

Violations of limit values
Important parameters, such as imbalance, should be checked continuously to protect important operating resources, by separating them from the grid in better time.

In association with the data logger violations of limit values may be recorded with the time of their occurences.

Fundamental and distortion reactive power
The reactive power may be divided in a fundamental and a distortion component. Only the fundamental reactive power may be compensated using the classical capacitive method. The distortion component, which originate from harmonic currents, have to be combated using inductors or active harmonic conditioners.

Rectifiers, inverters and frequency converters are only a few examples of components generating distortion reactive power. But normally only in industrial grids it may represent a real problem.

System imbalance
System imbalance not only occurs due to single phase load situations, but is often a sign for disturbances in the grid, such as isolation failure, phase failure or earth-leakage. Three phase loads are often very sensitive to operating voltages provided imbalanced. This may lead to a shorter lifetime or even damage.

An imbalance monitoring therefore not only helps to save costs in maintenance but also prolongs the undisturbed operating time of the used production facilities.
THE DISPLAY

The APLUS offers all which is requested from a device with display:
- Excellent legibility from almost any distance and each angle
- Clear and explicit display of measured data
- Free composition of measurement displays
- Free allocation of alarms to status LED’s
- Free definable plaintext display for alarming
- Preference display and roll mode

DISPLAY MODES

FULL: All measurement displays in a matrix representation, selected via arrow keys. Fourth line used for meter display.
REDUCED: Same as FULL mode but with facility to hide individual measurement displays.
USER: Up to 20 free composable measurement displays, selected with and . The fourth line may be used to display meter contents or system quantities (P,Q,S,U,I).
LOOP: Measurement displays of the USER mode will be displayed successively for a definable time.

PROGRAMMING

On the device ratios of current and voltage transformers, parameters of the communication interface, threshold values of limit value, time and date as well as display settings can be modified.
Selectively per measurement group the registered min/max or meter values may be reset.

ALARM+METERS

The occurrence of an alarm state can be signalized via the yellow LED’s. The corresponding alarm text will be displayed by shortly pressing . At the same time instead of the measured quantities their identification is shown for a second.
For reading the 8-digit meter contents the key must be pressed longer than 2 seconds. Using and you may scroll through all the values.

SECURITY SYSTEM

All programming functions may be locked selectively by means of the PC software. They then are not at the user’s disposal when operating the display unit.
Also for the access via interface the alteration of device data may be granted or locked per group.

Parametrization, service and measurement acquisition

The supplied CB-Manager software provides the following functions to the user:
- Complete parametrization of the APLUS (also offline)
- Acquisition and recording of measured quantities
- Archiving of configuration and measurement files
- Setting or resetting of meter contents
- Selective reset of extreme values
- Setting of interface parameters
- Simulation of logic module or outputs functions
- Comprehensive help system

A security system can be activated to restrict the access to device data. This way e.g. changing a limit value via display can be locked, but a setting via configuration could still be possible.
Free composition of the required functions

The APLUS basic unit is already comprehensively equipped with a relay output for alarming, a digital output, e.g. for pulse output, and a digital input, e.g. for tariff switching.

For applications where this is not sufficient, the optional I/O extensions 1 or 2 are available (see graphic).

Possible applications of the I/Os

Relay outputs
- Alarming via lamp or horn
- Load shedding
- Self monitoring signal of APLUS (via relay of basic unit)
- Remote controllable via bus interface

Digital outputs 1)
- Alarm output of the logic module
- State reporting
- Pulse output to external counters (acc. EN62053-31)
- Remote controllable via bus interface

Analog outputs
- Connection to PLC or another measurement system (e.g. CAM)
- All outputs are bipolar (±20 mA) and galvanically isolated.

Digital inputs 1)
- Meter tariff switching
- Operating feedback of loads for operating time counters
- Trigger and release signal for logic module
- Pulse input for any meters
- Clock synchronization
- Synchronization of billing intervals

1) The digital I/O’s of the I/O extensions can individually be configured for input or output.

Order code APLUS - . . . . .

1. Basic unit APLUS
   With LED display, for panel mounting
   1

2. Input frequency range
   45...50/60...65 Hz
   1

3. Auxiliary power supply
   Nominal voltage 24...230 V DC, 100...230 V AC
   1

4. Communication interface
   RS485, Protocol Modbus/RTU
   1
   Ethernet, Protocol Modbus/TCP, NTP
   2

5. I/O extension
   Without
   0
   2 relays, 4 analog outputs ±20 mA, 2 digital I/O’s
   1
   2 relays, 6 digital I/O’s
   2

6. Test certificate
   Without
   0
   Test certificate in German
   D
   Test certificate in English
   E

7. Data logger
   Without data logger
   0
   With data logger
   1

Accessories

<table>
<thead>
<tr>
<th>Item</th>
<th>Order no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface converter USB &lt;-&gt; RS485</td>
<td>163 189</td>
</tr>
<tr>
<td>Connection set: Plug-in terminals, mounting clamps 3)</td>
<td>168 220</td>
</tr>
<tr>
<td>Plug-in terminals I/O extension 4)</td>
<td>168 232</td>
</tr>
</tbody>
</table>

3) Available as from 07-2010 4) scope of supply
### Technical data

#### Inputs

**Nominal current:** adjustable 1...5 A  
Maximum: 7.5 A (sinusoidal)  
Consumption: \( \leq I^2 \times 0.01 \Omega \) per phase  
Overload capability: 10 A continuous  
100 A, 10 x 1 s, interval 100 s

**Nominal voltage:**  
57.7...400 V\(_{\text{LN}}\), 100...693 V\(_{\text{LL}}\)  
Maximum: 480 V\(_{\text{LN}}\), 832 V\(_{\text{LL}}\) (sinusoidal)  
Consumption: \( \leq U^2 / 3 \text{M}\Omega \) per phase  
Impedance: 3 M\(\Omega\) per phase  
Overload capability: 480 V\(_{\text{LN}}\), 832 V\(_{\text{LL}}\) continuous  
600 V\(_{\text{LN}}\), 1040 V\(_{\text{LL}}\), 10 x 10 s, interval 10 s  
800 V\(_{\text{LN}}\), 1386 V\(_{\text{LL}}\), 10 x 1 s, interval 10 s

**Systems:**  
Single phase  
Split phase (2 phase system)  
3-wire, balanced load  
3-wire, unbalanced load  
3-wire, unbalanced load, Aoron connection  
4-wire, balanced load  
4-wire, unbalanced load  
4-wire, unbalanced load, Open-Y

**Nominal frequency:** 45...60 / 60...65 Hz

**Measurement TRMS:** up to 63rd harmonic

#### Measurement uncertainty

**Reference conditions:** Ambient 15...30°C, sinusoidal, measurement over 8 cycles, \(PF=1\), frequency 50...60 Hz

**Voltage, current:** \( \pm (0.08\% \text{MV} + 0.02\% \text{MR})^{1,2} \)  
**Power:** \( \pm (0.16\% \text{MV} + 0.04\% \text{MR})^{3,4} \)  
**Power factor:** \( \pm 0.1^\circ \)  
**Frequency:** \( \pm 0.01 \text{Hz} \)  
**Imbalance U,I:** \( \pm 0.5\% \)  
**Harmonics:** \( \pm 0.5\% \)  
**THD voltage:** \( \pm 0.5\% \)  
**TDD current:** \( \pm 0.5\% \)  
**Active energy:** Class 0.5S, EN 62053-22  
**Reactive energy:** Class 2, EN 62053-23

#### Power supply:

**Nominal voltage:** 100...230 V AC ±15%, 50...400 Hz  
24...230 V DC ±15%

**Consumption:** \( \leq 7 \text{VA} \)

#### I/O-Interface

**Basic device:**  
1 relay output, changeover contact  
1 digital output (fixed)  
1 digital input (fixed)

**I/O extension 1:**  
2 relay outputs, changeover contact  
4 bipolar analog outputs  
2 digital inputs/outputs

**I/O extension 2:**  
2 relay outputs, changeover contact  
6 digital inputs/outputs

**Analog outputs:** via plug-in terminals, galvanically isolated  
Linearization: Linear, quadratic, kinked  
Range: \( \pm 20 \text{mA} \) (24 mA max.), bipolar  
Uncertainty: \( \pm 0.2\% \) of 20 mA  
Burden: \( \leq 500 \Omega \) (max. 10 V / 20 mA)  
Burden influence: \( \leq 0.2\% \)  
Residual ripple: \( \leq 0.4\% \)

**Relays:** via plug-in terminals  
Contacts: changeover contact, bistabil  
Load capacity: 250 V AC, 2 A, 500 VA  
30 V DC, 2 A, 60 W

**Digital inputs / outputs**  
Connection via plug-in terminals. For I/O extension individually configurable as input or output.

**Inputs (acc. EN 61 131-2 DC 24 V Type 3):**  
Nominal voltage 12 / 24 V DC (30 V max.)  
Logical ZERO – 3 up to + 5 V  
Logical ONE 8 up to 30 V

**Outputs (partly acc. EN 61 131-2):**  
Nominal voltage 12 / 24 V DC (30 V max.)  
Nominal current 50 mA (60 mA max.)  
Load capability 400 \(\Omega\) … 1 M\(\Omega\)

#### Interface

**Modbus/RTU** via plug-in terminals  
**Protocol:** Modbus RTU  
**Physics:** RS-485, max. 1200 m (4000 ft)

**Baud rate:** 2.4 up to 115.2 kBaud  
**Number of participants:** \( \leq 32 \)

#### Internal clock (RTC)

**Uncertainty:** \( \pm 2 \text{ minutes / month} \) (15 up to 30°C), trimmable via PC software  
**Synchronization:** via synchronization pulse  
**Running reserve:** > 10 years

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1 MV: measured value, MR: measurement range (maximum)  
2 Additional uncertainty for voltage measurement of 0.1% MV if neutral wire not connected (3-wire connections)  
3 MR: maximum voltage x maximum current  
4 Additional uncertainty of 0.1° if neutral wire not connected (3-wire connections)
Disposable measured quantities

Basic measured quantities

These measured quantities are determined using the configured measurement time (2...1024 cycles, in steps of 2 cycles). The display refreshment takes place with the refresh rate set.

<table>
<thead>
<tr>
<th>Measured quantity</th>
<th>present</th>
<th>max</th>
<th>min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage per phase, system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean value of voltages $U_{\text{mean}}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero displacement voltage $U_{\Delta}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum $\Delta U &lt;&gt; U_{\text{mean}}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase angle of voltages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current per phase, system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean value of phase currents</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral current $I_{n}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum $\Delta I &lt;&gt; I_{\text{mean}}$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Power quality analysis

These values are calculated about twice a second, depending on the system frequency.

<table>
<thead>
<tr>
<th>Measured quantity</th>
<th>present</th>
<th>max</th>
<th>min</th>
</tr>
</thead>
<tbody>
<tr>
<td>THD voltage per phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDD current per phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harmonics voltage 2nd – 50th per phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harmonics current 2nd – 50th per phase</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distortion reactive power per phase, system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fundamental reactive power per phase, system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\cos\phi$ fundamental per phase, system</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Meters

<table>
<thead>
<tr>
<th>Measured quantity</th>
<th>present</th>
<th>HT</th>
<th>LT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active energy incoming: per phase, system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active energy outgoing system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reactive energy incoming: per phase, system</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean-values

As a standard the mean-values of the system power quantities are determined over the same programmable interval time $t_1$. The interval time $t_2$ of the selectable mean-value quantities may be different but equal for all 12 quantities.

<table>
<thead>
<tr>
<th>Measured quantity</th>
<th>present</th>
<th>trend</th>
<th>max</th>
<th>min</th>
<th>history</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active power incoming 1 s…60 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Active power outgoing 1 s…60 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Reactive power incoming 1 s…60 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Reactive power outgoing 1 s…60 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Reactive power induct. 1 s…60 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Reactive power capac. 1 s…60 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Apparent power 1 s…60 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Mean-value quant. 1-12 1 s…60 min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

1) Maximum deviation from the mean-value of the 3 phase voltages
2) Maximum deviation from the mean-value of the 3 phase currents
3) Possible meters of the digital pulse inputs – any measurand and unit
4) Available via communication interface only, no indication on display
**Ambient conditions, general information**

Operating temperature: –10 … 15 … 30 … + 55°C  
Storage temperature: –25 up to + 70 °C  
Temperature influence: 0.5 x basic uncertainty per 10 K  
Long term drift: 0.2 x basic uncertainty per year  

Others: Usage group II (EN 60688)  
Relative humidity: < 95% no condensation  
Altitude: ≤ 2000 m max.  
Device to be used indoor only!

**Mechanical attributes**

Orientation: Any  
Housing material: Polycarbonat (Makrolon)  
Flammability class: V-0 acc. UL94, self-extinguishing, non-dripping, free of halogen  
Weight: 500 g  

Panel cut-out

**Safety**

The current inputs are galvanically isolated from each other.  
Protection class: II (protective insulation, voltage inputs via protective impedance)  
Pollution degree: 2  

Protection rating: IP64 (front), IP40 (housing), IP20 (terminals)  
Measurement category: CAT III, CATII (relays)

**Applied standards, regulations and directives**

IEC/EN 61 010-1  
IEC/EN 60 688  
DIN 40 110  
IEC/EN 60 068-2-1/2-3-6-27:  
IEC/EN 60 529  
IEC/EN 62 053-31  
2002/95/EG (RoHS)  

Safety regulations for electric measuring, control and laboratory equipment  
Electrical measuring transducers for converting AC electrical variables into analog or digital signals  
AC quantities  
Ambient tests  
Protection type by case  
EC directive on the restriction of the use of certain hazardous substances  
Electromagnetical compatibility (EMC)  
Generic standards for industrial environment  
Programmable controllers – equipment, requirements and tests (digital inputs/outputs 12/24V DC)  
Electrical equipment for measurement, control and laboratory use – EMC requirements  
Pulse output devices for electromechanical and electronic meters (SO output)  
Test for flammability of plastic materials for parts in devices and appliances

**Rely on us.**

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