Instruction manual

ipsensor

Table of contents

1 Introduction 5

2 Installation 6

2.1 Assembly 6

2.2 Schematics 10

2.3 The ipsensor 12 CT..11

3 Software and Communication..12

3.1 System configuration..14

3.1.1 Installation of the ipsensor Service Tool 14

3.1.2 Program start..15

3.1.3 General configurations and communication with the base 15

3.1.3.1 Language selection..15

3.1.3.2 Sensor connection 15

3.1.3.3 Modbus ID 16

3.1.3.4 TCP/IP address 16

3.1.3.5 Serial Configuration 16

3.1.3.6 Connecting 17

3.1.3.7 Display of sensors 17

3.1.4 Base configuration..17

3.1.4.1 Serial communication configuration..18

3.1.4.2 IPv4 communication configuration..19

3.1.4.3 NTP configuration..21

3.1.5 Update base 22

3.1.6 Find base units in the subnet 23

3.1.7 Assign Modbus IDs..23

3.1.8 Assigning the Sensors 24

3.1.9 Configuration for the individual metering points in the sensors..25

3.1.10 Read out sensor measurements 26

3.2 Configuration of the adjustable Modbus registers..27

3.2.1 Configuration process 27

3.2.2 Sensor configuration 28
3.2.3 Configuration of the devices 29
3.2.4 Register configuration 30
3.2.5 Register functions 31
3.2.6 Readout of register values 33
3.2.7 Writing of register values in a file 33
3.2.8 Options for .csv delimiters 34
3.2.9 Saving of register configuration 34
3.2.10 Reset of active energy counter 35
3.2.11 Possible conflicts and errors 35

3.3 Operation 38

3.3.1 Addresses of adjustable Modbus registers 39
3.3.2 Addresses of the predefined Modbus registers 39

4 Glossary 43

5 Technical data 45

6 Safety instructions 47

7 Declaration of conformity 51

Appendix A Basis of calculation by EN 61557-12:2008 53

A.1 Active power (P) and active energy (Ea) 53

A.1.1 Second values 53
A.1.2 Single phase values 53
A.1.3 Three phase values 53

A.2 Idle power (Q) 54

A.2.1 Second values 54
A.2.2 Single phase values 54
A.2.3 Three phase values 54

A.3 Apparent power (S) 54

A.3.1 Second values 54
A.3.2 Single phase values 55
A.3.3 Three phase values 55

A.4 Current (I) 55

A.4.1 Second values 55

A.4.2 Single phase values 55

A.4.3 Three phase values 56

A.5 Voltage (U) 56

A.5.1 Second and mean values Lp-N 56

A.5.2 Second and mean values Lp-Lg 56

A.6 Power factor 57

A.6.1 Second values 57

A.6.2 Single phase values 57

A.6.3 Three phase values 57

Editor:		Document:	SYC000628
GT elektronik GmbH & Co.KG		Revision:	7
Schlörstraße 3		Last modified:	23.07.2020
92507 Nabburg			

1 Introduction

ipsensor serves as detailed power measurement of single loads in 50 / 60 Hz low voltage systems. The data of such power measurement may then be used to carry out measures to e.g. improve the energy efficiency as part of an Energy Management System. The power measurement is done at the leads which exit the circuit breakers for the single devices within a low voltage distributor.

The modular system is composed of a base and one or more sensors. The sensors are equipped with several metering points to measure the power of multiple loads. The different versions of sensors differ in the number of metering points and the respective nominal current.

The sensors are connected to the base via a flat ribbon cable (Sensorbus). The measurements and the supply voltage required for the sensors are transferred via this flat ribbon cable. During installation, the flat ribbon cable is finished to fit the individual conditions of the respective facility.

The base and circuit breakers are mounted on a top hat rail (TS35). The sensors are mounted on the circuit breakers.

The Modbus Protocol works as interface to read the power values. ipsensor supports the protocol versions Modbus-TCP and Modbus-RTU.

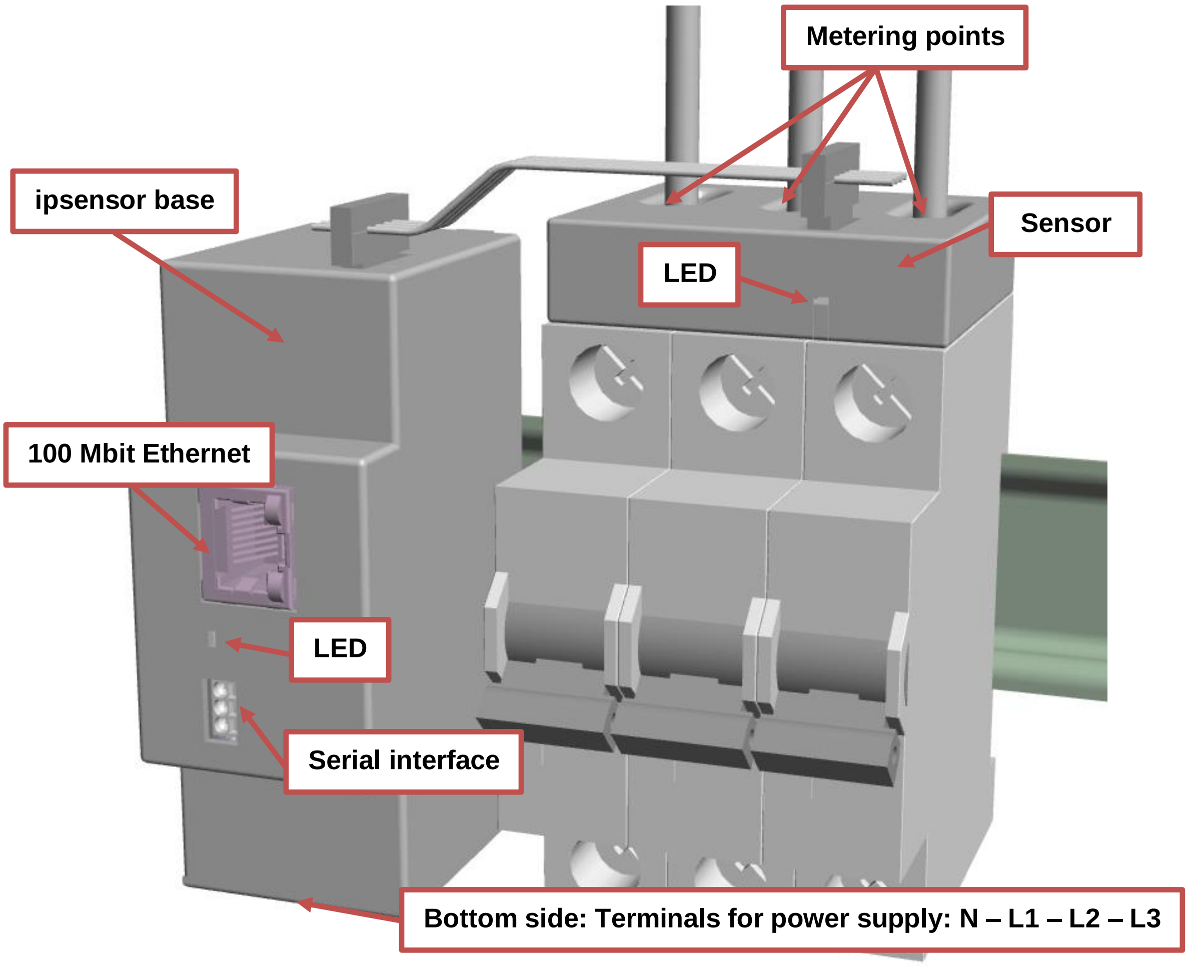


Figure 1: Graphic representation of the ipsensor

2 Installation

Please completely read this installation and operator's manual in its entirety before you install and start the ipsensor! This manual contains important safety information and is based on the technical stage of 07.07.2019. We reserve the right to update without prior announcement the information given in this manual.

2.1 Assembly

General safety instructions:

The electrical installation and startup may only be carried out by a qualified licensed electrician respecting the following indications. An inappropriate execution of installation and startup may lead to damages and/or endanger people.

ipsensor is only designed for usage in single and three- phase low voltage systems with a nominal voltage of 230 / 400 V AC at 50 resp. 60 Hz.

Prior to installation all voltage carrying connections and measurement leads must be disconnected from the mains.

Figure 2: Slider on the base module

The base is fixed by means of a slider on top-hat rail (TS35) (**Figure 2**).

Power supply via terminals (voltage entries) on bottom side (**Figure 3**).

For fastening, slide the connection lead into the respective terminal. To disengage, use the orange release key.

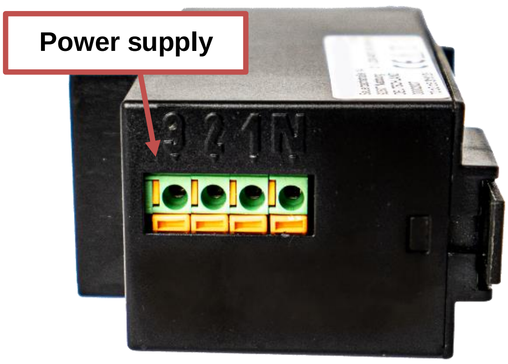


Figure 3: Voltage entries of the base module

Only L1 and N are connected in single phase systems. In tri-phase systems all phases and N are connected.

The terminals are marked with their respective use.

⚠	Voltage entries L1, L2, L3 must be secured by circuit breakers 1A, release characteristic B. A method must be provided which allows the device to be disconnected from the power supply, e.g. a clearly marked circuit breaker or fused disconnector.

Conductor cross sections for L1, L2, L3 and N:

Single wire:	0,5 mm^2 – 1,5 mm^2
Wire stripping length:	10 mm
Fine-wired with insulated ferrule:	0,5 mm^2 – 1 mm^2

Important: The voltage connection of the base is installed in such a way that the stripped blank connection wire can be touched. The base must be installed respectively covered in such a way that the area of the voltage connection is covered.

Figure 4: Circuit breakers with detached power supply line

Before fixing the sensors, any existing power lines must be disconnected (see **Figure 4**). Before working on these lines, they must be disconnected from the power supply.

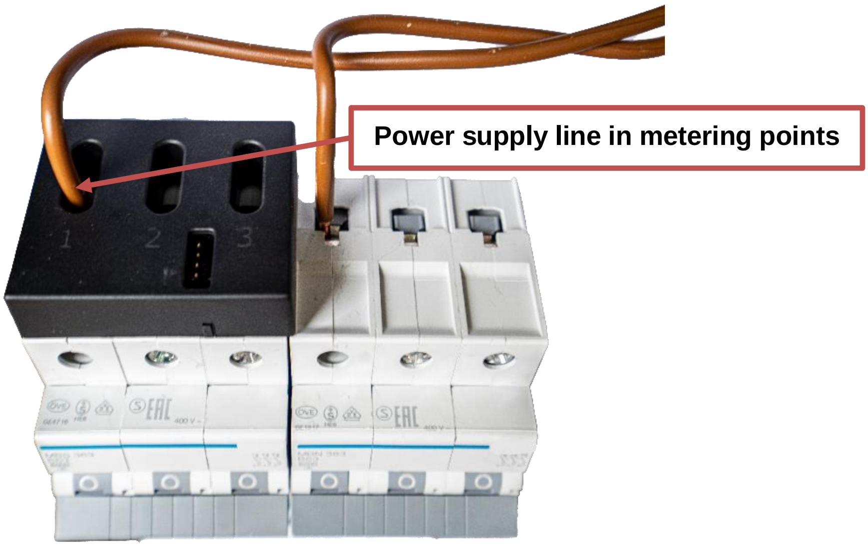


Figure 5: Power supply line in the metering point of a sensor

The power supply lines are fed through the openings of the metering points and then reconnected (**Figure 5**).

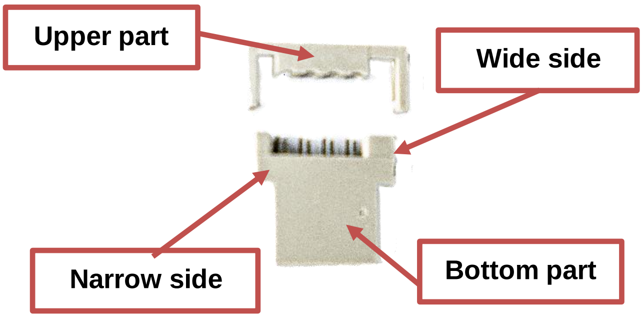


Figure 6: Plug for the flat ribbon cable

The plugs for the flat ribbon cable are assembled with upper and bottom part (**Figure 6**). Note that the plugs are not symmetrical.

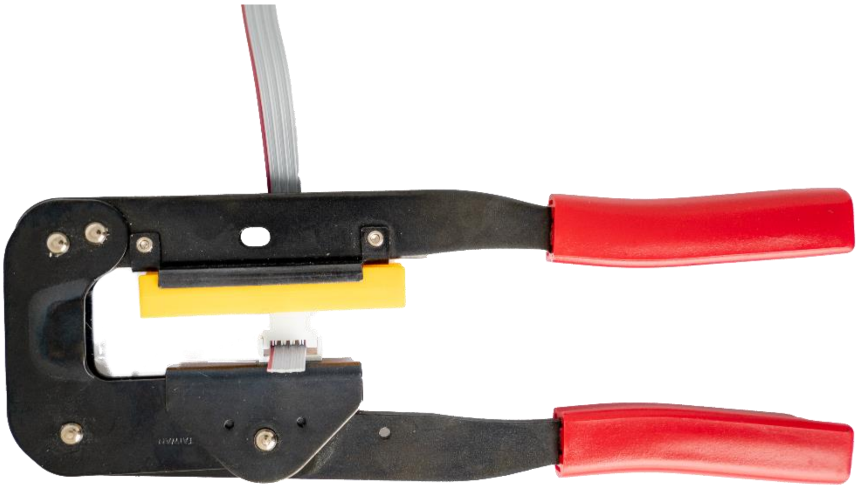


Figure 7: Flat ribbon cable and plug with pliers

Use appropriate pliers to squeeze the plugs onto the cable (**Figure 7**).

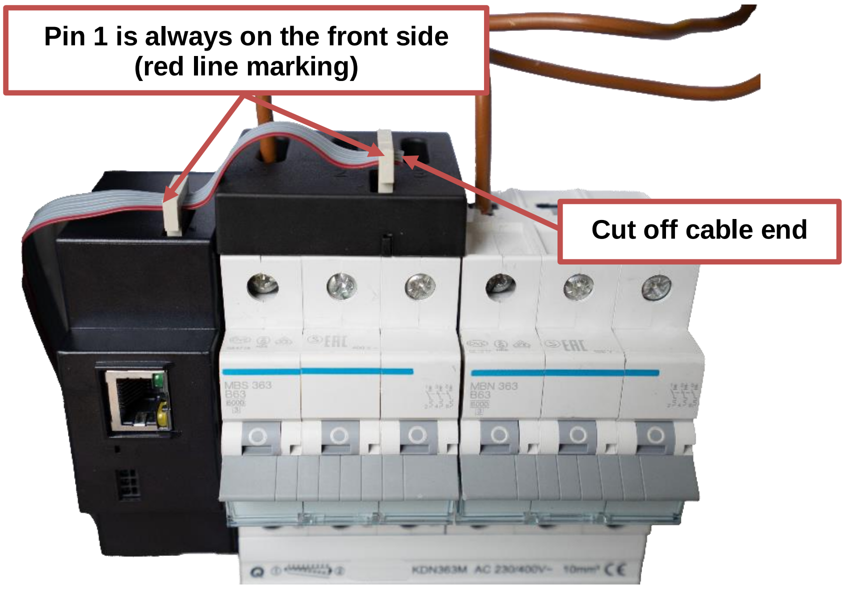


Figure 8: Flat ribbon cable connected with base module and sensor

The base and all sensors are connected with a flat ribbon cable. As shown in **Figure 8**, the plugs are put in the Sensorbus interfaces of the base and of the voltage sensors:

- The connectors are squeezed onto the cable at appropriate intervals.
- The sensors may be connected to both the left and the right side of the base.
- The order of the sensors on the cable is irrelevant.
- Only one central unit can be connected.

- **Important**: Pin 1 of the cable must always be on the front of the base and all sensors.
- **Important**: The cut off cable end has no insulation. Keep the cable ends away from non-insulated low voltage cables. Maintain a minimum distance of 6 mm. Shrink-tube the open ends.

2.2 Schematics

The schematic visualization of the ipsensor measurement system with base module and sensor is shown below (**Figure 9**). The sensor is powered by the base, and the base is powered by the grid. The power lines of the load are wired through the metering points of the sensor.

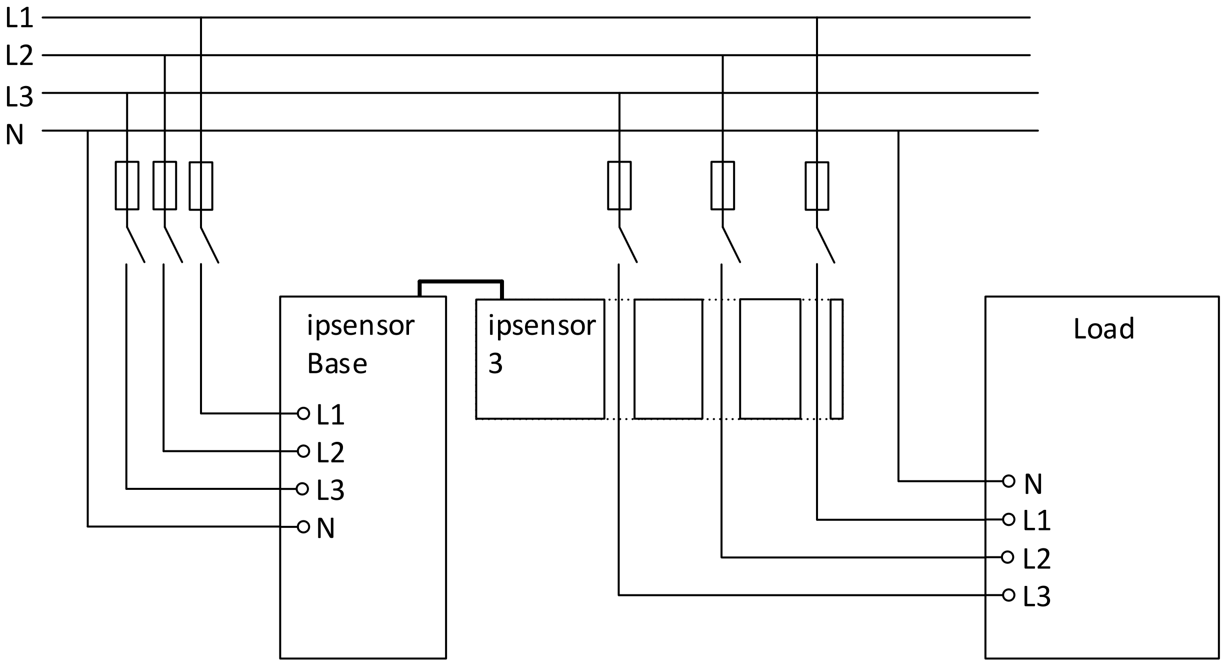


Figure 9: Schematics of the ipsensor

2.3 The ipsensor 12 CT

The ipsensor 12 CT is a current and power measuring sensor that is connected to current transformers. The converter (for example a folding converter) is put around the power lines of the load and connected to a metering point of the CT sensor, to record measuring data. The sensor is attached to the top-hat rail, like the base unit, and connected with the base over the CAN.

The schematics of the wiring for an ipsensor 12 CT can be seen in **Figure 10**.

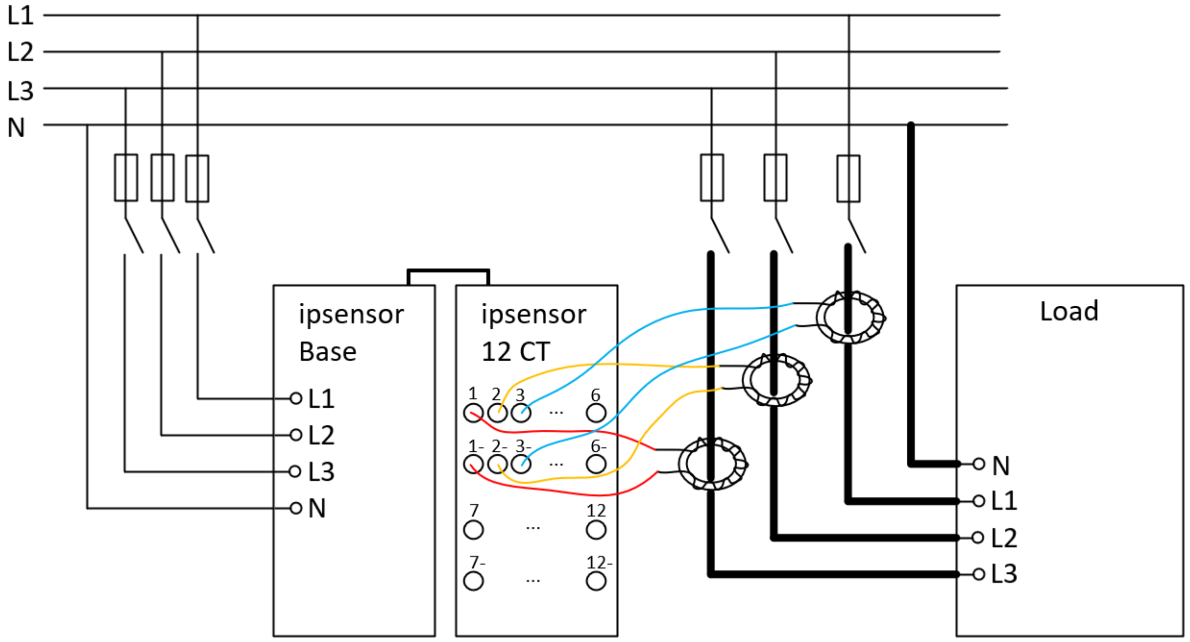


Figure 10: Schematics of the ipsensor 12 CT

The ipsensor 12 CT has 12 metering points. There are 4 rows, each with 6 inputs, on the surface of the sensor. A combination of an upper and a lower input makes up one metering points. Thus, the two top rows include metering point 1 to 6, from left to right, and the two bottom rows include metering point 7 to 12.

3 Software and Communication

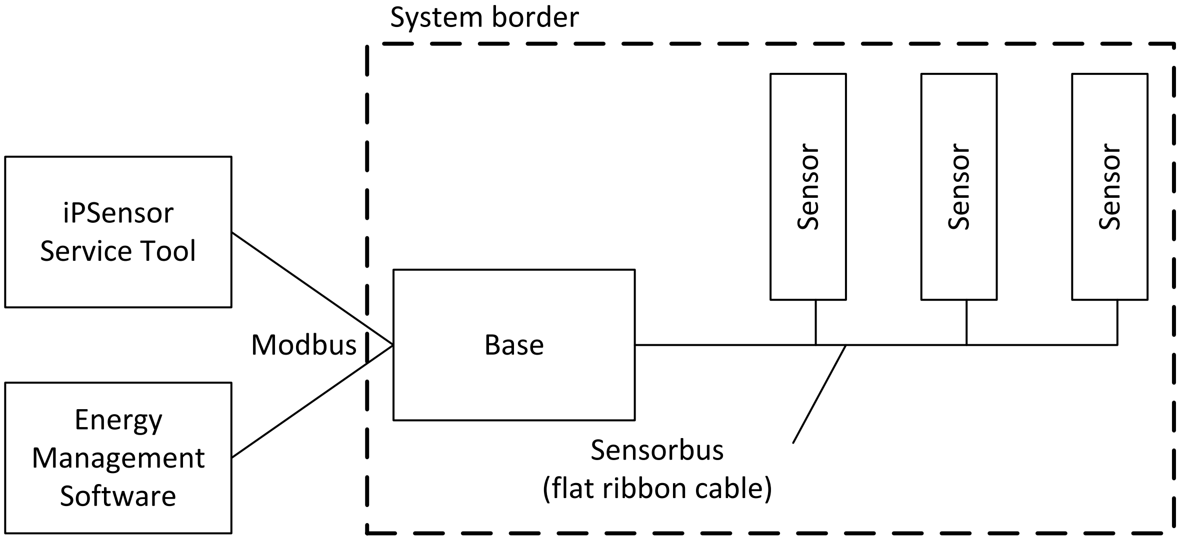


Figure 11: Schematic representation of the ipsensor

ipsensor has an internal interface via which the base communicates with the sensors. Communication to the outside takes place via the connections of the base (**Figure 11**).

ipsensor has a Modbus interface as external interface. Both Modbus TCP (via Ethernet) and the Modbus RTU (via RS485) protocols are supported. This document assumes a basic understanding of these protocols. The communication can be carried out via one of the two interfaces, but it is also possible to use both interfaces alternatively. All functions are available on both interfaces.

ipsensor is supplied with a .net based configuration program (ipsensor Service Tool). This program is used to configure the measuring system and it requires .net framework, version 4.0. The operation of this tool can be found in the chapters on configuration.

For operation, an energy management software is required, which can read Modbus registers and process the corresponding data. This software is not part of the delivery. The interface via which this software accesses the measured data can be found in the chapter "Operation".

The configuration possibilities for this software must be described by the manufacturer of the corresponding software.

Modbus TCP communication is via a 100 Mbit Ethernet interface with a RJ45 plug on the front of the device.

Modbus RTU communication is via a RS485 interface, which has three terminals on the front of the device.

For Modbus RTU communication, the following communication parameters must be set for the first connection:

Start bits	**1**
Stop bits	**1**
Parity	**Even**
Baudrate	**115,2 KBaud**

The ipsensor Service Tool sets the required parameters for the serial interface itself. These parameters can be individually configured later with the ipsensor Service Tool.

The picture shows the communication interfaces of the base (**Figure** 12).

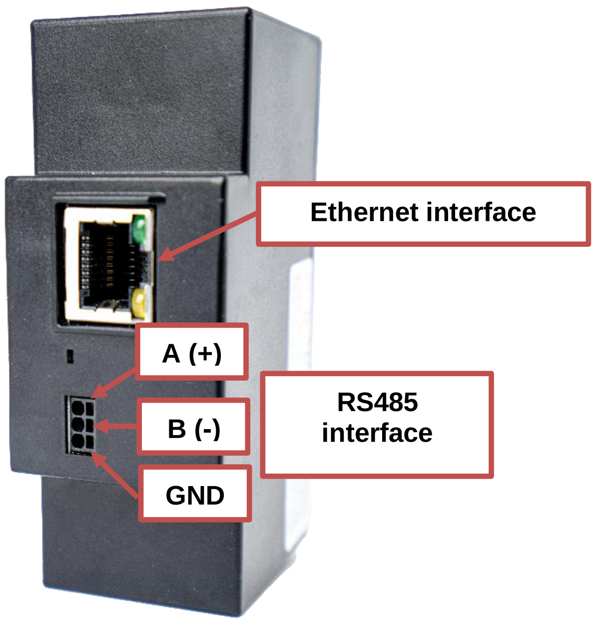


Figure 12: Communication interfaces of the base module

The Ethernet interface must be connected with an Ethernet cable CAT5 or better with a 100Mbit switch.

The RS485 interface is connected via the terminals. The picture shows the assignment of the signals to the base. The connection wire must only be pushed into the respective terminal for fixing. Release is done with the release button.

Conductor cross sections for A(+), B(-), GND:

Fine-wire with insulated wire end ferrule: 0,25mm²

The termination of the RS485 interface in the device corresponds with this wiring:

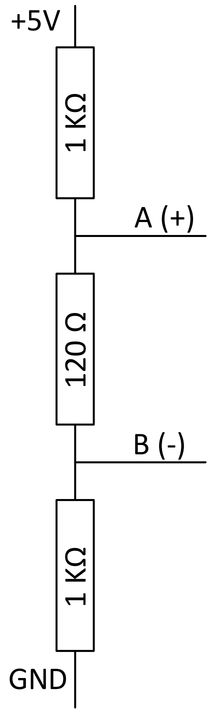


Figure 13: RS485 interface in the device

3.1 System configuration

ipsensor is configured using the ipsensor Service Tool. This is used in particular for the following settings:

- Setting of base communication parameters (IP address or Modbus ID)
- Assignment of the sensors with their metering points to free sensor slots
- Assignment of the respective phases of the voltage measurement to the metering points of the sensors
- Definition of the logic devices and setting of the adjustable registers

3.1.1 Installation of the ipsensor Service Tool

The installation of the ipsensor service tool is done by a setup file. The user needs write permission in the installation directory.

3.1.2 Program start

To start, run the executable „ControlFramework.exe“. The program starts with its start screen (**Figure 14**). The system configuration is done via this screen. The screen is divided into three parts.

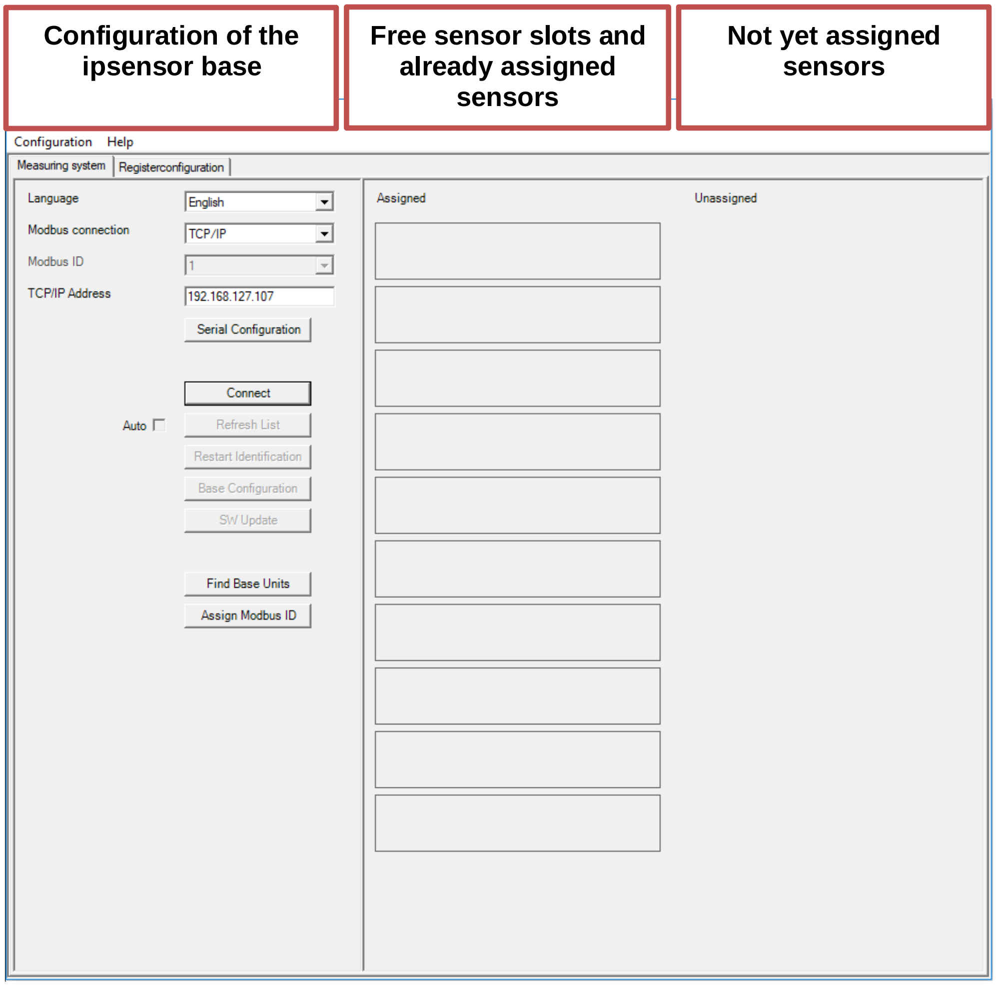


Figure 14: ipsensor Service Tool Frontpage

3.1.3 General configurations and communication with the base

3.1.3.1 Language selection

The operating language of ipsensor Tool is set via language selection.

3.1.3.2 Sensor connection

The sensor connection is used to determine whether the ipsensor service tool is to communicate with the base via TCP / IP or the serial interface. Depending on the selection, only the corresponding additional fields are available.

3.1.3.3 Modbus ID

This parameter is used for communication via the serial interface. This parameter sets the Modbus ID for communication with ipsensor Base on the serial interface. The parameter is also relevant for the reading of Modbus registers. In the delivery condition, each base has Modbus ID 1. The selection is done via a list, values between 1 and 31 can be selected.

If the base is to be addressed via the serial interface after delivery, a Modbus must be used in which no other device uses the ID 1.

In case of communication via TCP/IP with the base, the Modbus ID is ignored in the telegrams. In this case, the addressing is exclusively carried out via the base IP address.

3.1.3.4 TCP/IP address

This parameter is only used for communication via TCP/IP. The parameter is used to set the IP address for communication with the respective base in the network. Alternatively, the hostname of the base can be used if it is set before and if DHCP is enabled.

In the delivery state, each base has the IP address 0.0.0.0. Once the base is powered, it will try to receive a new IP address via DHCP. If, after delivery, the base is to be addressed via TCP / IP, a subnet must be established in which this address can be addressed by the ipsensor service tool.

The manual setting procedure of the IP address is described in chapter „Base configuration".

3.1.3.5 Serial Configuration

This button sets the parameters of the serial interface, which is used by the ipsensor software to communicate with the base module (**Figure 15**).

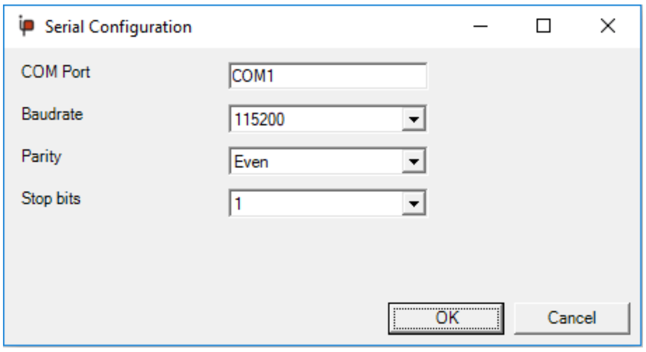


Figure 15: Serial parameters of the configuration tool

The first parameter is used to determine which serial interface of the PC (COM port, for example COM1) is to be used to communicate with the base. The selection is done via a suitable entry in the text box.

Additionally, the drop-down menus for the baudrate, parity and stop bits provide several different options for an individual configuration of the serial parameters.

3.1.3.6 Connecting

After successful connection to the respective system, the user has access to the other options on the interface. After disconnecting, they are deactivated again.

During connection, identification is made as to which sensors are connected to the base.

3.1.3.7 Display of sensors

The current status of the sensors can be read with the button "Refresh list". If the "Auto" checkbox is activated, the sensor status will be refreshed every 3 seconds. With the "Restart Identification" button, the configuration is reset, and the connected sensors are identified again.

The function and meaning of the display are explained in detail in the chapter "Assigning the Sensors".

3.1.4 Base configuration

The button „Base Configuration“ opens a window for the base configuration. In this window, single setting values of the base can be read out and the communication parameters of the central unit can be changed (**Figure 16**).

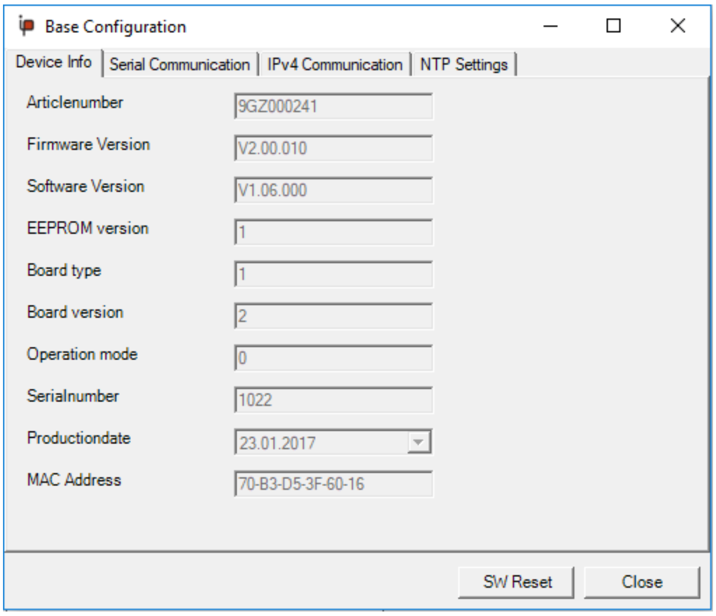


Figure 16: Base configuration – Device Info

The „Read” button in the respective line is used to read out the corresponding parameter of the base. The “Write” button is used to write the parameters in the base. Parameters without a “Write” button cannot be changed by the user. Their display is for information purposes only.

The tab “Device Info” shows general and unchangeable information about the base. The button “SW Reset” can restart the base.

3.1.4.1 Serial communication configuration

The tab “Serial Communication” is for the configuration of the serial port of the base unit (**Figure 17**).

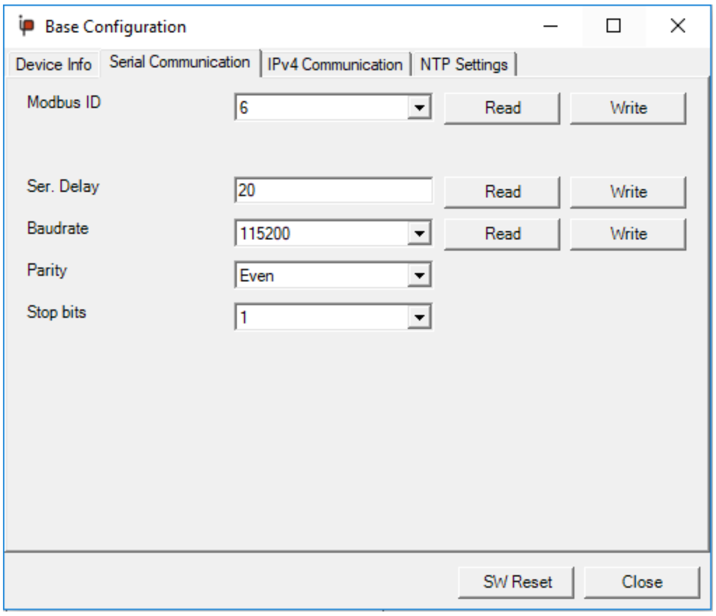


Figure 17: Base configuration - Serial Communcation

The Modbus ID is the ID with which the base may be addressed on the Modbus. The assignable values are displayed in a selection editor. Values between 1 and 31 are possible.

The ipsensor base answers the "Read Register" commands on the Modbus RTU interface with an adjustable delay, the serial delay. During this delay, the polling device must change the data flow direction on the interface from Send to Receive. Depending on the device, this can take a different time. The parameter can be used to set the delay in ms, thereby optimizing the scan speed.

The baudrate, parity and stop bits are the serial parameters of the base module. The parameters will only be used by communication via the serial interface. There are several options to choose from, display via drop-down menus. The “undefined” option cannot be written to the base and only exists for reading from the base.

3.1.4.2 IPv4 communication configuration

The tab “IPv4 Communication” is for the configuration of the TCP/IP parameters of the base unit (**Figure 18**).

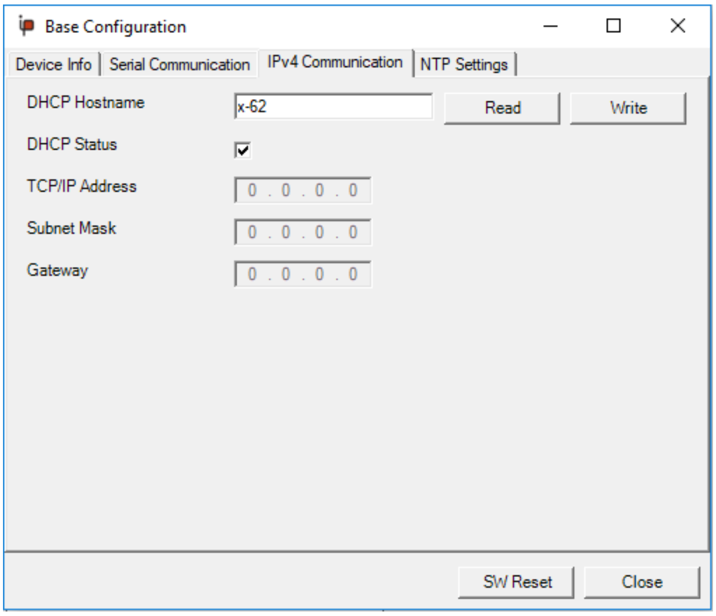


Figure 18: Base configuration - IPv4 Communcation

The TCP/IP address is the ID with which the base may be addressed via TCP/IP. The IP address can be changed in this field. After a change, the connection has to be closed, the new IP address has to be entered in the Service Tool’s communication area and the connection might have to be re-established.

If DHCP is enabled, manually setting the IP parameters is disabled, because the base receives them automatically. It is possible to connect to the base via a hostname, which can be set here. The hostname cannot be longer than 16 characters.

If DHCP is disabled, a new static IP address with a plausible subnet mask has to be set as well.

Alternatively, the TCP/IP address can also be set via a ping command, if DHCP is disabled. The software of ipsensor base reacts to Ethernet ping messages as follows:

A ping message always contains a MAC address and an IP address. The MAC address may also be a broadcast address (0). Ping messages where the MAC address corresponds with the MAC address of ipsensor base (no broadcast), set the transferred IP address as new IP address in the ipsensor base

To achieve this, follow these steps for a Windows PC:

- The PC must have an own IP address in the same subnet as the desired IP address of ipsensor.
- For the MAC address of the ipsensor base (which is located on the article number sticker on the back of the hardware), a static entry must be generated in the ARP table of the PC.
- A shell in administrator mode is opened.
- The command ***netsh interface show interface*** is used to display the Ethernet interfaces

- The command ***netsh interface ipv4 add neighbors*** *"Name of the LAN-connection" „IP“ „MAC“* is used to create a new ARP entry.

  Example: ***netsh interface ipv4 add neighbors Ethernet 192.168.127.88 70-B3-D5-3F-60-FF***
- Using the command ***arp –a*** the entries can be displayed. There must be a static entry for the new desired IP address at the interface, which is located in the same subnet. Example:

```
Schnittstelle: 192.168.127.106 --- 0xf
  Internetadresse       Physische Adresse     Typ
  192.168.127.88        70-b3-d5-3f-60-ff     statisch
  192.168.127.92        70-b3-d5-3f-60-0a     dynamisch
  192.168.127.200       68-b5-99-52-11-4e     dynamisch
  192.168.127.201       00-14-38-91-8f-b7     dynamisch
  192.168.127.254       00-90-7f-e2-b6-05     dynamisch
```

- Using the command ***ping „IP“,*** a ping message with the MAC address of the ipsensor central unit and the new IP address is sent to the ipsensor base.

  Example: ***ping 192.168.127.88***

  The desired IP address is thusly registered.
- The command ***arp –d „IP“*** deletes the static ARP entry.

  Example: ***arp –d 192.168.127.88***
- Afterwards the Service Tool can be used to communicate with ipsensor via the new IP address.

The Subnet Mask is only used for communication via TCP/IP. The parameter defines the subnet mask of the subnet in which the base is installed.

The Standard gateway is only used for communication via TCP/IP. The parameter specifies the TCP/IP address of the default gateway in the subnet where the base is installed. The TCP/IP address, the subnet mask and the standard gateway are all checked for plausibility before being set.

3.1.4.3 NTP configuration

The tab “NTP Settings” is for writing the addresses of NTP servers to the base and activating / deactivating the NTP service (**Figure 19**).

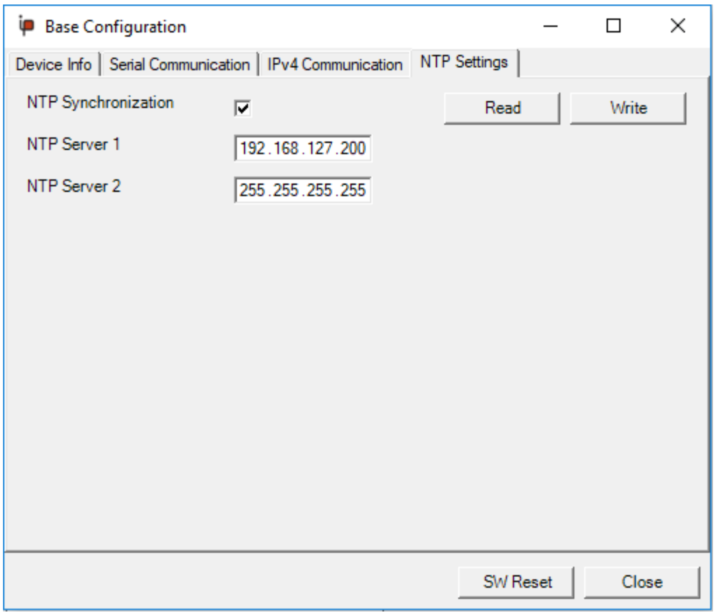


Figure 19: Base configuration - NTP Settings

If the ipsensor base is connected to the network via TCP/IP, it can get the current time value from an NTP Server. The time value is used to adjust the current interval of the selected interval length for the mean value calculation to the full hour of the current time of day.

The TCP/IP addresses of two NTP servers can be configured. With NTP synchronization enabled, the ipsensor base will try to get the current time value from NTP server 1 shortly after startup. If this server is not available, NTP server 2 will be used instead. If NTP server 2 is not available either, the central unit will try to reach NTP Server 1 again.

If both servers do not answer for several seconds, the central unit will show an unsynchronized state by a fast blink mode of the LED.

3.1.5 Update base

Press the „SW Update“ button to update the software of all connected components. A dialog box opens for the update (**Figure 20**).

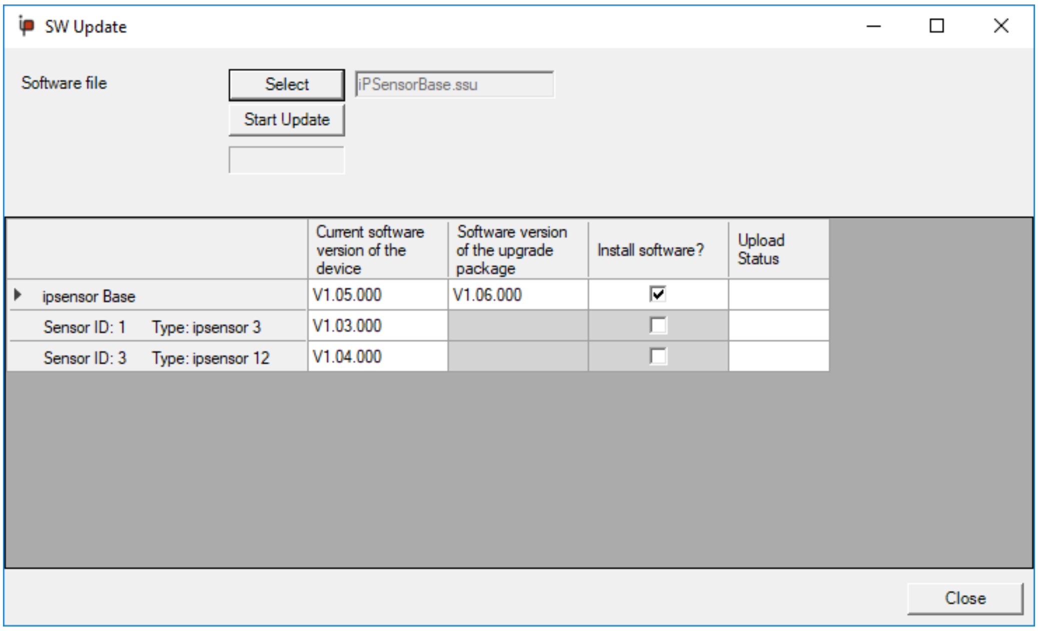


Figure 20: Software Update - Base

The corresponding ".ssu" file must be selected in the file dialog window. After that, the checkboxes of all components corresponding to the selected update file will be enabled. By pressing the "Start Update" button all selected components will be updated.

The progress of the update is displayed on the progress bar and in the status column of the data grid below. By pressing the “Stop” button, the update of multiple components will be stopped after the currently updating component has finished.

If the window is closed while a component is being updated, the update will be terminated. The currently updating component might be left with a corrupted software. In this case, the component can only be used again once a successful software update has been executed.

3.1.6 Find base units in the subnet

With the button “Find base units”, all base modules in the subnet, with the latest software installed, can be found. Pressing it will open a window with a table, listing information about the connected base units, like the product name, the serial number, the IP communication parameters and the MAC address (**Figure 21**).

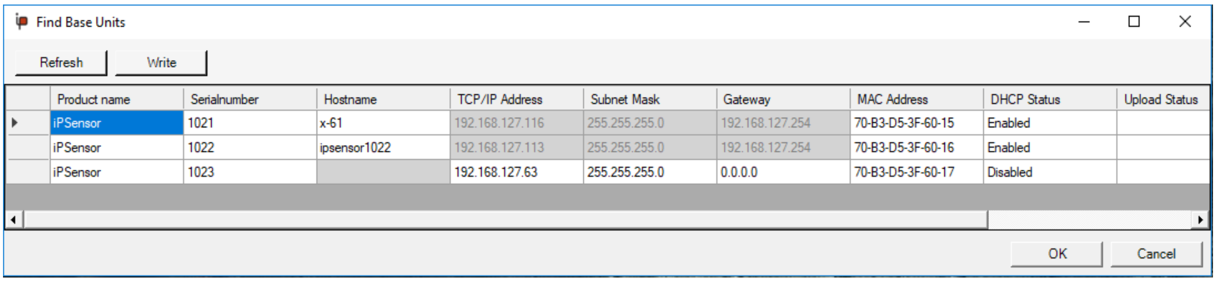


Figure 21: Find base units

The button “Refresh” recreates the table with updated information about the found base units in the subnet. The IP communication parameters (IP address, subnet mask, gateway) of the base modules can be changed and they will be uploaded in the specific base by pressing the “Write” button. The parameters will be checked for plausibility before uploading. The status of the uploaded parameters will be shown in the “Upload Status” column.

If the DHCP Status is enabled, the IP parameters will be set automatically and will then be displayed. A hostname can be set to communicate with the base unit instead of the normal IP address.

If DHCP is disabled, a new static IP address with a plausible subnet mask has to be set manually. Base units that do not support DHCP yet are displayed with grey cells in the DHCP columns.

3.1.7 Assign Modbus IDs

With the button “Assign Modbus ID”, the Modbus IDs of all over the serial port connected base units can be read and written via their serial number (**Figure 22**).

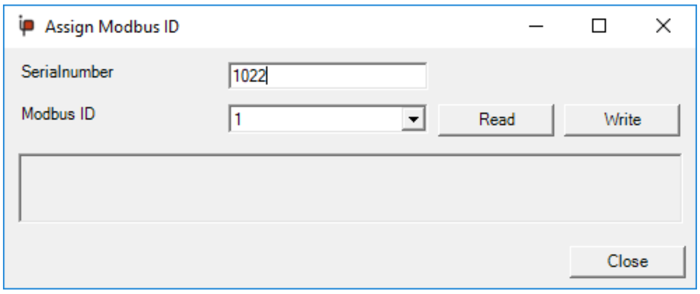


Figure 22: Assign Modbus ID

If the serial port is open, the Modbus IDs of all base units that are connect over this serial port can be read and written via their serial numbers. This is especially important if two base units that are on the same serial port have the same Modbus ID.

3.1.8 Assigning the Sensors

A list of connected sensors is read out from the base by pressing the button “Connect” or “Restart Identification”. Each sensor has a unique serial number (**Figure 23**).

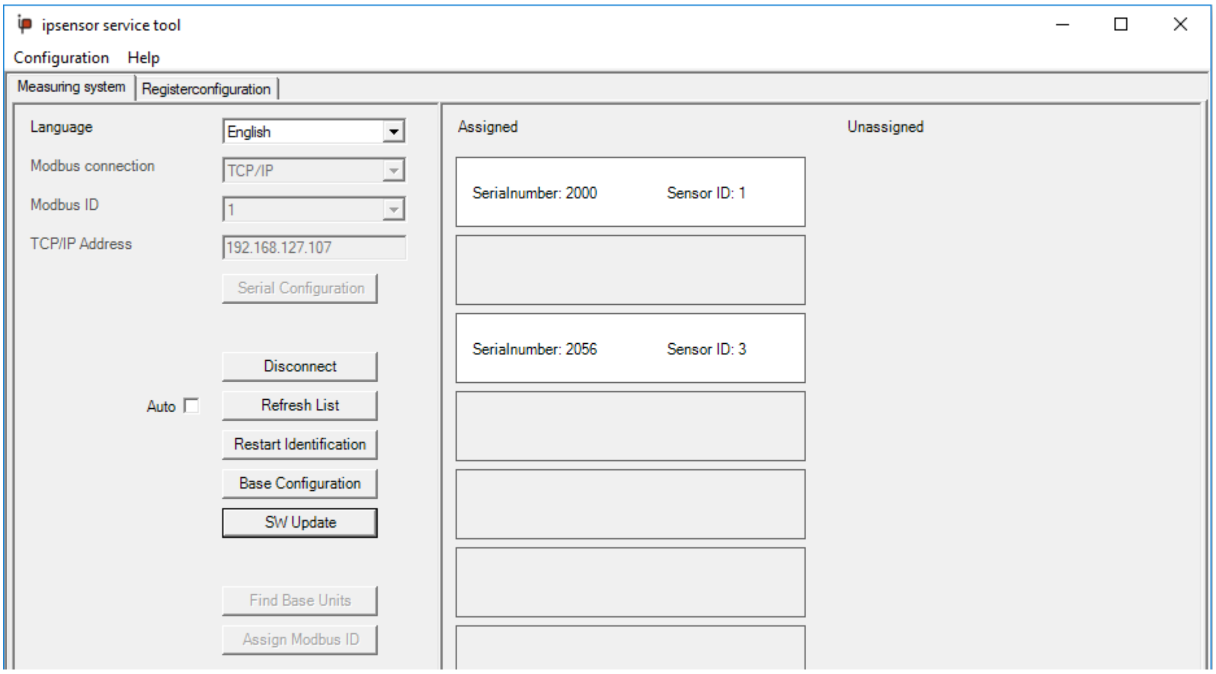


Figure 23: connected ipsensor Service Tool

When assigning the sensors, an individual ID is assigned to the individual sensors. The ID corresponds to a sensor location within the system and is later used to read out the registers of the respective sensor. In the respective box symbolizing a sensor, both the ID and the serial number can be seen **(Figure 23)**.

After the read out, the non-assigned sensors are displayed, blinking in red-white, in the right column. Sensors with an ID assigned, are displayed in white in the left column.

Errors of the assigned sensors are displayed as follows:

State	Description
Display blinks green	The sensor has not yet synchronized with the base. The blue LED on the sensor blinks rapidly.
Display blinks yellow	The sensor has not started the application because it is defective. A new application has to be loaded into the sensor
Display blinks red	The sensor no longer responds to the sensor bus

An update of the error conditions is scanned via the button „Refresh List“. With the auto checkbox activated, the status is automatically updated every 3 seconds.

When the mouse cursor is over a sensor, this sensor is displayed in blue on the PC surface. At the same time, the LED of the corresponding physical sensor is switched on. Via the illuminated LED, the sensor can easily be identified in the configuration view of the system.

To assign an ID to a sensor, simply drag the corresponding sensor to a sensor location while holding down the left mouse button. If the sensor location is already occupied, the existing sensor is automatically pushed to the next higher position.

3.1.9 Configuration for the individual metering points in the sensors

Open the context menu "Sensorconfiguration" with a right mouse click on the sensor to open the window for the sensor configuration (**Figure 24**).

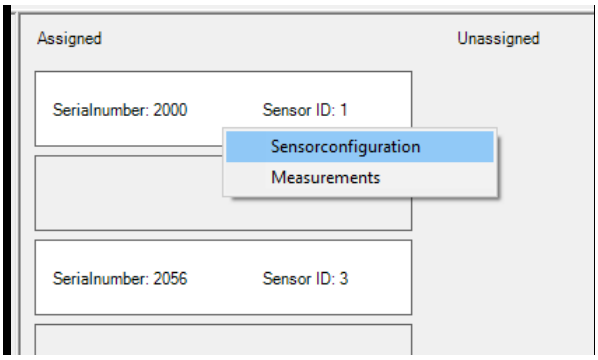


Figure 24: Right-clicking on a sensor

In this window, the corresponding voltage phase for each metering point, as well as the current direction for the entire sensor, is set (**Figure 25**). For the CT sensors, the polarity and the turns ratio can be configured per metering point (**Figure 26**). By hitting OK, the regulated values for each sensor are saved for the respective sensor.

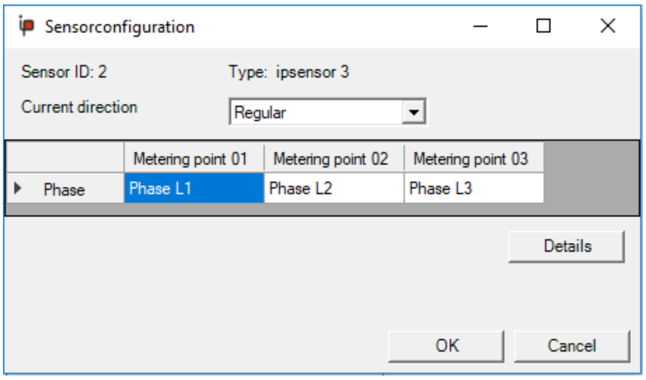


Figure 25: Sensorconfiguration of an ipsensor 3

When using adjustable Modbus registers, the phase assignment has to be carried out when creating the register configuration. This process is described in chapter "Sensor configuration".

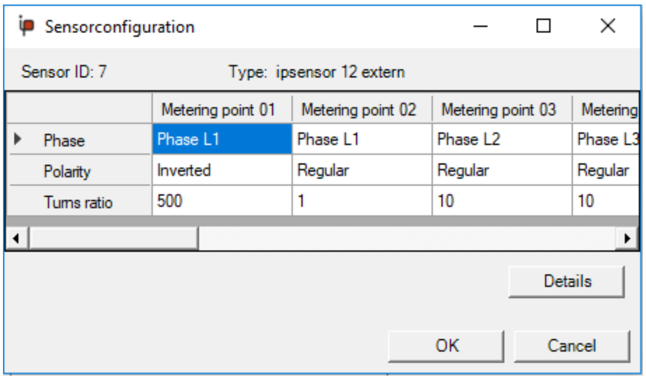


Figure 26: Sensorconfiguration of an ipsensor 12 CT

By clicking on the "Details"-Button, the window for the sensor details is opened. Various configuration values of the sensors can be read in the window. The display is for information only, the user cannot change the settings.

3.1.10 Read out sensor measurements

Via a context menu which is opened by right-clicking on a sensor, the window for reading the current measured values is opened (**Figure 27**).

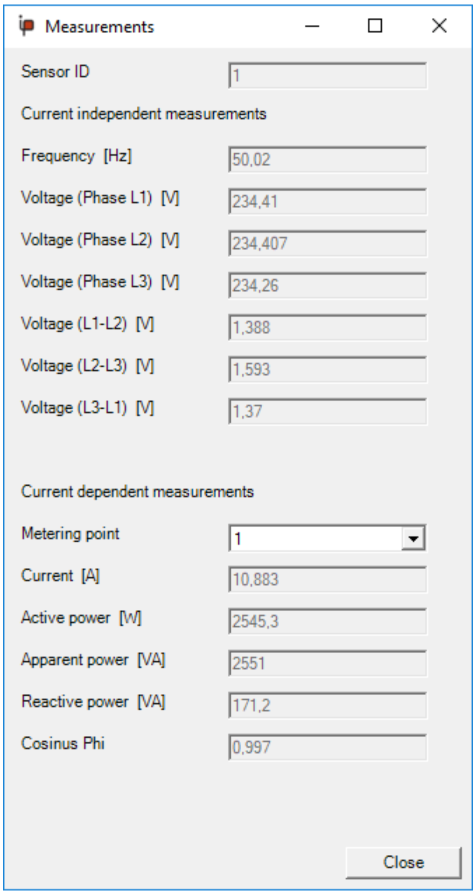


Figure 27: Measurements

This window contains a general section in which the measured voltage values are displayed for all phases. The metering point is selected in the specific metering point part. The current and power values are displayed for this selected metering point. The editors display the values by second. The measurements are updated every second.

3.2 Configuration of the adjustable Modbus registers

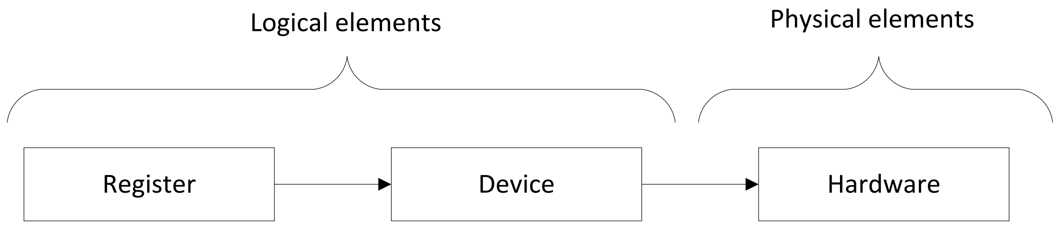
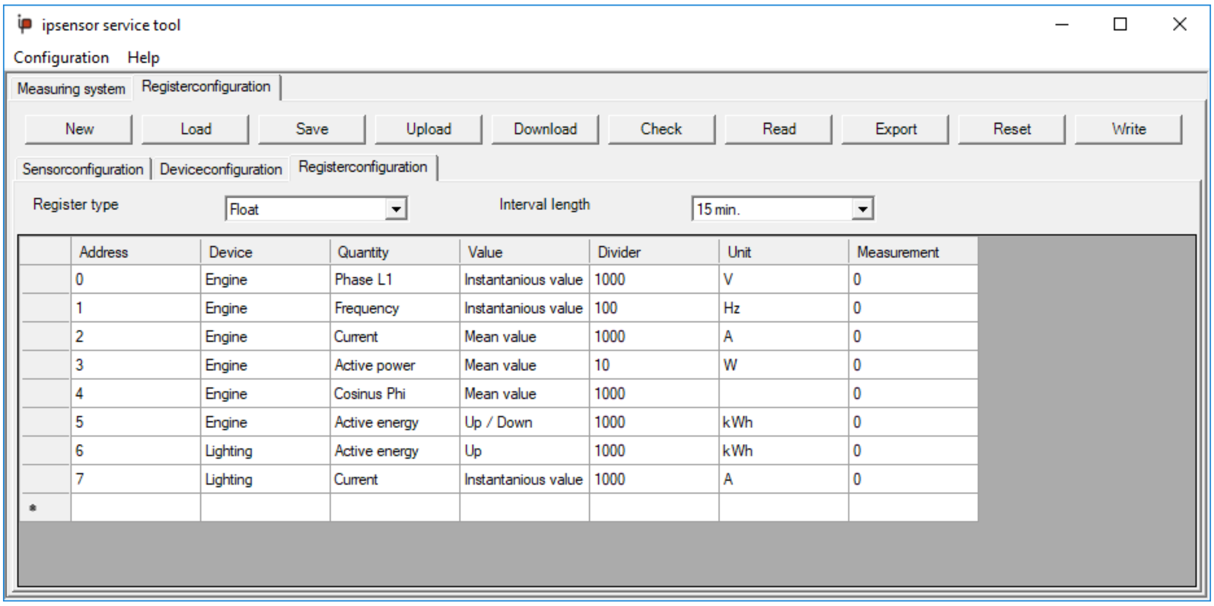


Figure 28: Schematic of the registerconfiguration

ipsensor offers an outwards logical register interface via the register configuration. The user defines devices to access the metering system ipsensor. A device may have one or three phases and may use the according number of metering points. The user may create registers for the single devices which supply the quantities of the complete device, e.g. active power or Cos Phi. With the ipsensor service tool, the user may configure the range of the adjustable registers (**Figure 29**).



Address	Device	Quantity	Value	Divider	Unit	Measurement
0	Engine	Phase L1	Instantanious value	1000	V	0
1	Engine	Frequency	Instantanious value	100	Hz	0
2	Engine	Current	Mean value	1000	A	0
3	Engine	Active power	Mean value	10	W	0
4	Engine	Cosinus Phi	Mean value	1000		0
5	Engine	Active energy	Up / Down	1000	kWh	0
6	Lighting	Active energy	Up	1000	kWh	0
7	Lighting	Current	Instantanious value	1000	A	0

Figure 29: Registerconfiguration of the ipsensor

3.2.1 Configuration process

Use tab “Registerconfiguration” on ipsensor Service Tool to configure the adjustable registers. The configuration may be saved in a file and loaded from the file. In order to process the configuration, no connection of the service tool to an ipsensor measuring system is required. The configuration can be checked offline for logic errors.

Once created, the configuration can be uploaded into the metering system. Prior to uploading, the configuration has to be tested for logical errors and compatibility with the hardware.

The configuration may also be downloaded from the hardware.

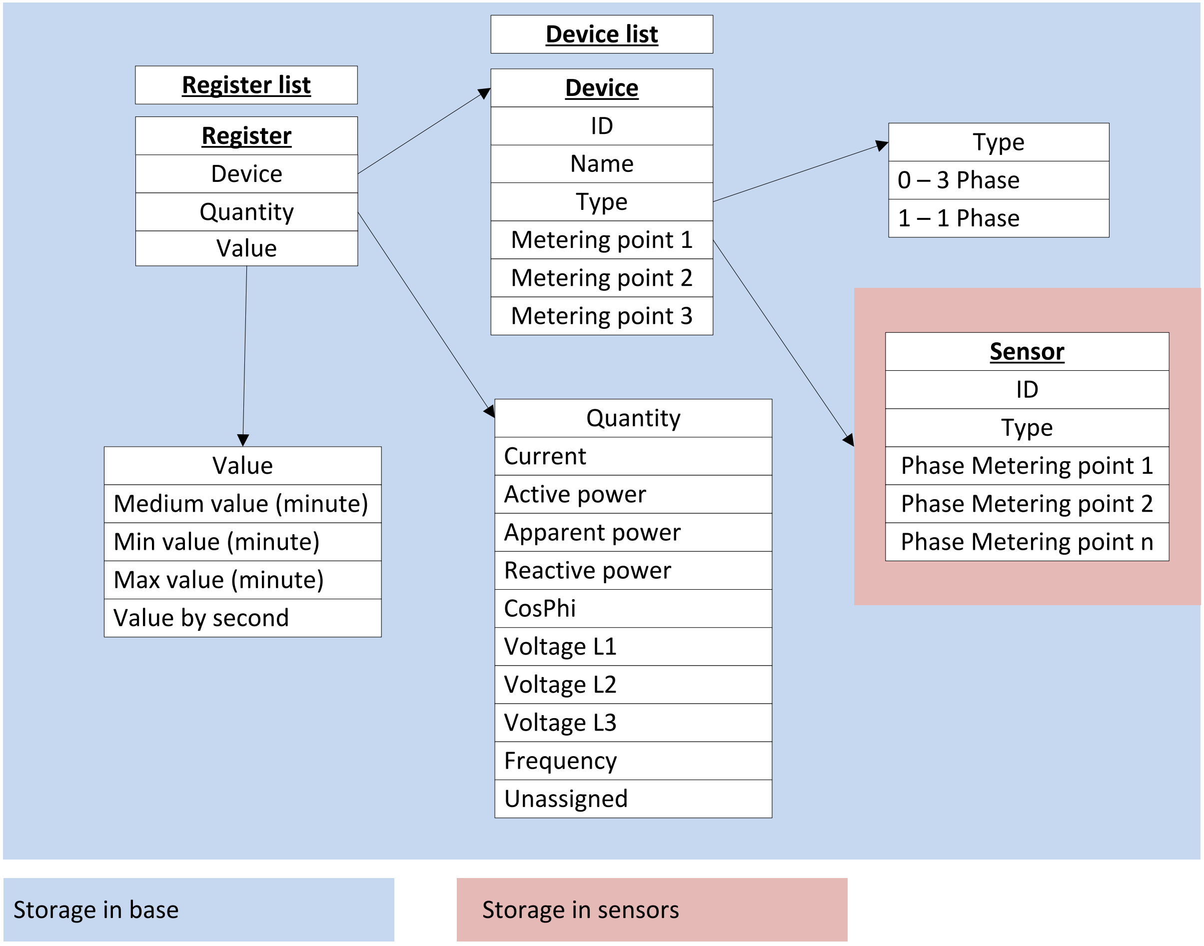


Figure 30: Schematic of the configuration

The configuration consists of the elements with their respective attributes shown in the diagram. When saving in a file, all elements are stored in a configuration file. Storing in ipsensor hardware means that the registers, devices and texts are saved in the base.

The available sensors store the phase assignment to each metering point. The configuration may also be downloaded from the measurement system.

3.2.2 Sensor configuration

The sensors can be configured in the “Sensorconfiguration” tab (**Figure 31**). The sensors must match the available sensors (IDs) of the device.

The phase of the corresponding conductor has to be set for each metering point. Additionally, the current direction flowing through a sensor can be set. This has to be done per metering point for external sensors (= CT sensors). These external sensors also provide the opportunity to configure the turns ratio per metering point.

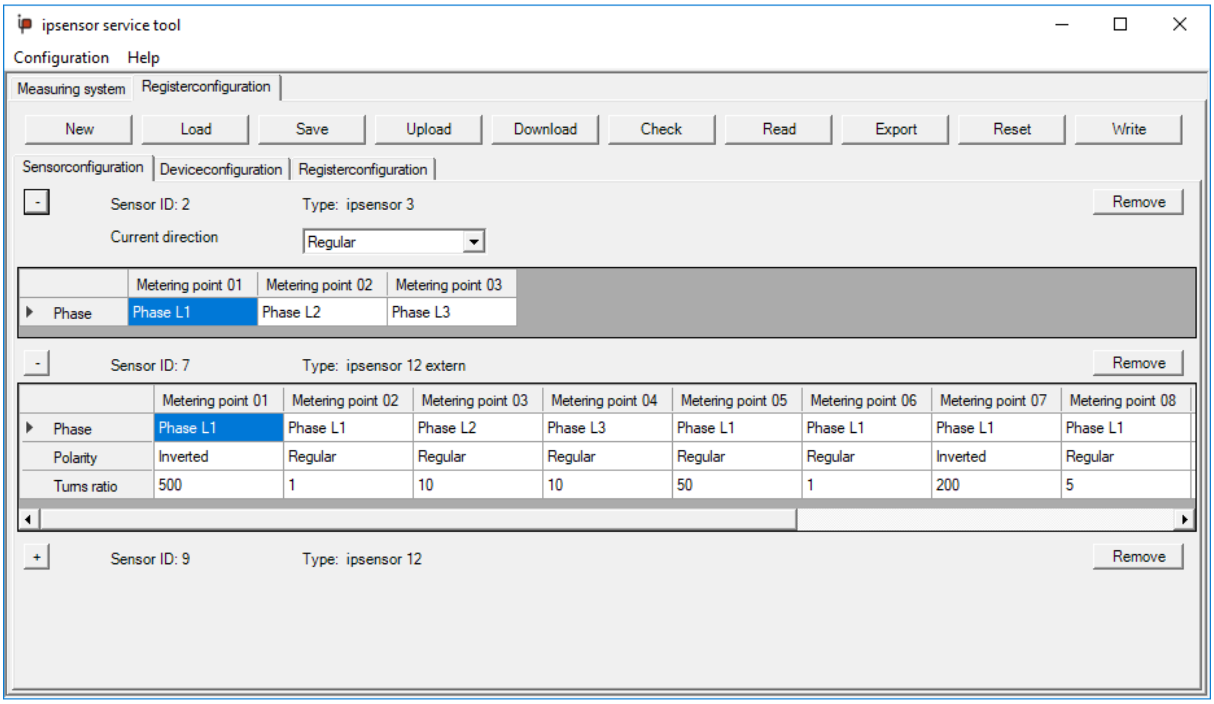


Figure 31: Sensorconfiguration of ipsensor

Via the menu item „Configuration“, by clicking “Sensor setup”, new sensors can be added to the configuration (**Figure 32**). The sensor ID and type cannot be changed after adding a new sensor, but the sensor can be removed and configured anew.

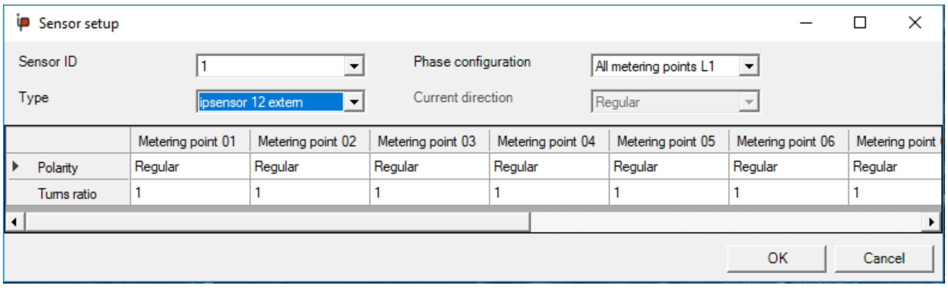


Figure 32: Sensor setup

3.2.3 Configuration of the devices

The devices can be configured in the “Deviceconfiguration” tab (**Figure 33**). Up to 120 devices may be created. The devices receive a name for identification during the configuration process and an ID from 0 to 255. The ID is given by the user and must be unique. Gaps are permitted and the order is arbitrary. Each device is either single phase or three-phase configured. Corresponding with the number of phases, one or 3 metering points have to be assigned. In the case of three-phase devices, no defined order for the three phases L1, L2 and L3 must be maintained.

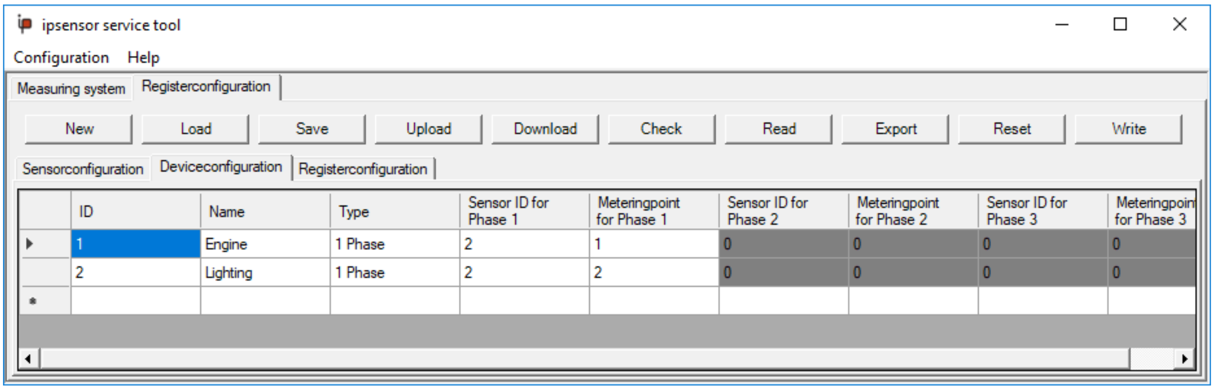


Figure 33: Deviceconfiguration of ipsensor

For easier operation, a tool for configuring devices automatically has been implemented in the menu bar on “Configuration“ by pressing the menu item “Device setup“ (**Figure 34**).

The name and type (1 phase or 3 phases) of the device can be selected, and then the metering points of the created sensors can be assigned.

There is an option to hide all already assigned metering points in the selection. After enabling this option, if the metering point editor is empty, that means that all metering points of that sensor have already been assigned.

Before creating the device, all entries are checked for validation and in case they are not, an error message will be displayed.

The device ID will be automatically assigned on the next free ID when using this tool.

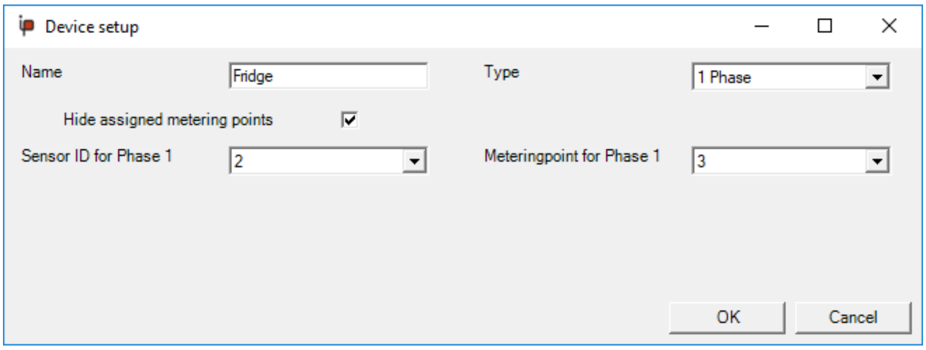


Figure 34: Device setup

3.2.4 Register configuration

In the tab “Registerconfiguration”, the Modbus registers can be configured (**Figure 29**). Up to 2,032 32 Bit registers can be created. Each register represents a quantity for the device. This value corresponds to a distinct combination of device, quantity and value.

The registers must have a distinct internal address between 0 and 2,031. Gaps are permissible and the order is arbitrary.

During readout from the Modbus, an offset of **0xC000 HEX / 49,152 DEC** is added to the internal register address.

Because it is 32 Bit registers

- it takes two 16 Bit Modbus registers to be read out. The bit 0 of the address differentiates the high and the low register.
- the internal register address has to be multiplied by 2 for the address calculation of the Modbus.

The measurements are transferred as Big Endian data. The data in the “Read holding register” messages have the following meaning:

Register N		Register N+1	
Byte 3 (MSB)	Byte 2	Byte 1	Byte 0 (LSB)

Alternatively, the tool to automatically create a registerconfiguration can be used: The menu item “Register setup” can be accessed via the menu “Configuration” in the menu bar. A popup window will be opened with several variants for the automatic registerconfiguration (**Figure 35**).

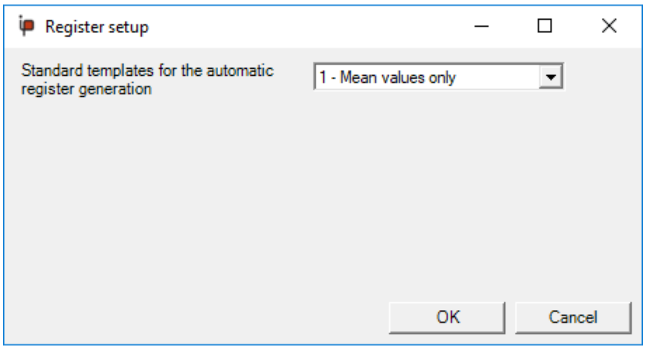


Figure 35: Register setup

The different variants for the automatic registerconfiguration can be chosen from a drop-down list. By pressing the “OK” button, the registers will be created automatically with the chosen register variant for all of the devices in the registerconfiguration.

3.2.5 Register functions

The registers represent a physical address. Each address has an SI unit.

To support the access of different types of management software, these addresses may be readout as single precision float in the usual IEEE 754 bit display or as 32 Bit Integer. The change is made via “register type” setting.

Since the requirements for the accuracy of the values also requires digits after the decimal point, the read out value must be divided by a divider when using the integer interface in order to obtain the correct result.

Quantity	Unit	Divisor
Amperage	A	1000
Active power	W	10
Apparent power	VA	10
Reactive power	VA	10
CosPhi	-	1000
Voltage	V	1000
Frequency	Hz	100
Active energy	kWh	1000
Line to line voltage	V	1000

The following values are offered for each quantity:

Value	Description
Mean value	Created during one minute by default The measurement is updated once per interval length.
Minimum	Created during one minute by default The measurement is updated once per interval length.
Maximum	Created during one minute by default The measurement is updated once per interval length.
Instantaneous value	Created during one second The measurement is updated once per second.

The interval length of the mean, minimum and maximum value is adjustable in the register configuration. Its default value is one minute.

The register for the active power is special:

It is a counter accumulating the value of the active power and may be read out via the register. For this reason, the distinction between minimum, maximum, mean and instantaneous value is meaningless. Instead, the manner of counting can be selected:

Value	Description
Up / Down	The counter accumulates both positive and negative active power values.
Down	The counter accumulates only negative active power values.
Up	The counter accumulates only positive active power values.
Unassigned	The counter doesn’t count.

The counter will be updated at the end of every measuring interval, by multiplying the corresponding mean value of the active power with the interval length of the measurement interval. Each device can only have one configured active energy counter.

3.2.6 Readout of register values

The configured register values can be read out with the “Read” button. The current measurements are displayed in the column „measurement“. The display in the column already considers the divider for the respective quantity.

3.2.7 Writing of register values in a file

With the “Write” button, the configured register values can be regularly read out (in an interval of every x seconds) and written into a simple .csv file or into a Microsoft Excel file. At the start of the writing process, the simple .csv file will be closed and it will be reopened once the “Stop” button is pressed. The file can also be opened during the writing process by pressing the “Open file” button. The Excel file does not have to be closed during the writing process and will be live updating the newly added measurement values.

As a third option, the writing of Splunk .csv files has been added. First, a folder can be selected, where all new .csv files are generated. The entire folder or single files can be analyzed with the IoT-platform Splunk (or any other IoT-platform that supports data analysis of .csv files). The name of the generated files is created from the device name with serial number and the date where the file was created. The size of the files is limited and a new file will be created, when the old one gets too big.

3.2.8 Options for .csv delimiters

The menu item “Options” can be accessed via the menu “Configuration” in the menu bar. By clicking on this menu item, a popup window will be opened displaying text boxes for the individualization of the currently used delimiters and decimal marks in the .csv files (**Figure 36**).

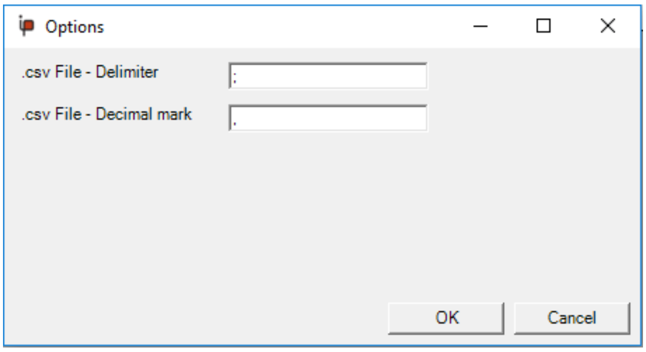


Figure 36: Options for .csv delimiters

At the first initialization, the delimiters of the .csv files will be chosen according to the current region settings of the computer. By pressing the „OK button, the entered delimiters will be saved. If one or both of these text boxes are empty while pressing the “OK” button, the delimiters will be reset to the current region settings of the computer.

3.2.9 Saving of register configuration

The register configuration can be written into a file with the “Export” button.

A dialog box opens where the file format can be selected. In case of the generic format, the columns contain this information:

Function	Comment
Register address	Decimal number Address on Modbus
Register quantity as index	0 amperage 1 active power 2 apparent power 3 reactive power 4 CosPhi 5 voltage L1 6 voltage L2 7 voltage L3 8 frequency

	9 active energy 10 line to line voltage L1-L2 11 line to line voltage L2-L3 12 line to line voltage L3-L1
Register quantity as text	
Device ID	Given by user
Device name as text	Given by user
Divisor	Decimal number Depending on the quantity
Value as index	0 mean value 1 minimum 2 maximum 3 value by second
Value as text	
Unit as text	Depending on the quantity

For the easy integration of ipsensor into other software environments, customized, specialized export files can be created. These can then be imported into the respective software in order to obtain easy access to the configured registers. The export differs according to the use of float or integer registers. For each register a name is created from the name of the used device, the respective quantity and the value.

When using umlauts, make sure that the respective software can also import files with umlauts.

3.2.10 Reset of active energy counter

Pushing the „Reset“ button performs a reset of either all or individual counters for the active energy.

3.2.11 Possible conflicts and errors

The configuration is tested for errors with the installed hardware and for logical errors within the configuration. The user gets a prompt with a description of the conflict. The loading process in the system is terminated.

In case of warnings, the configuration may be uploaded in the system.

Logical conflicts can be detected without a system.

At first, the configuration is tested for logical errors. When the configuration is free from logical errors, it is tested for compatibility with the hardware.

Conflict	Type of conflict	Type of error
A sensor ID is included in the configuration but not in the system	hardware	error
A sensor ID is included in the system but not in the configuration	hardware	warning
The configuration includes a sensor with more metering points than the respective sensor in the system	hardware	error
The configuration includes a sensor with less metering points than the respective sensor in the system	hardware	warning
The phase of a metering point in use in the configuration is allocated differently than in the system	hardware	message The configuration value is written in the system
Two devices use the same ID	logic	error
The number of devices is bigger than permitted	logic	error
A device was assigned more than one energy counter	logic	error
A three-phase device was not assigned three metering points	logic	error
No metering point was assigned to a one-phase	logic	error

device		
No phase was assigned to a metering point in use	logic	error
A device was assigned a metering point without sensor	logic	error
A three-phase device was not assigned to three metering points with all phases	logic	error
A register accesses a device not included in the configuration	logic	error
The internal address of a register is larger than its max. admitted	logic	error
Two registers use the same internal address	logic	error
The memory consumption is too big due to long texts	logic	error
The type of a sensor in the configuration doesn't match the same sensor in the hardware setup	logic	error
An external sensor has a metering point with a turns ratio of less than 1	logic	error

3.3 Operation

During operation, the data is continuously measured and offered as Modbus register contents. The corresponding energy management software accesses the registers and uses the read data.

All measurements are saved as 32 Bit values. Two 16 Bit Modbus registers must always be read out for a complete measurement. The command "03 Read Holding Register" is used for readout.

The measurement values are transferred as big Endian data. The data in the “read holding register” messages have the following meaning:

Register N		Register N+1	
Byte 3 (MSB)	Byte 2	Byte 1	Byte 0 (LSB)

For the individual quantities there is a value with the data of the last second.

In addition there is minimum, maximum and mean value over an adjustable interval length (one minute by default). These values are updated every 15 seconds.

The registers display physical quantities as integers. Each quantity is in SI units.

Since the requirements for the accuracy of the value points are required by the decimal point, the integer value must still be divided by a divider in order to obtain the correct value.

The following quantities are offered

Metering	Indication	Unit	Divisor
Effective voltage value	for L1, L2, L3	V	1000
Frequency	only calculated using L1	Hz	100
Effective current value	For each metering point	A	1000
Active power	For each metering point	W	10
Apparent power	For each metering point	VA	10
Reactive power	For each metering point	VA	10
Cosinus Phi	For each metering point		1000
Active energy	For configured devices	kWh	1000
Line to line voltage	For L1-L2, L2-L3, L3-L1	V	1000

3.3.1 Addresses of adjustable Modbus registers

Up to 2,032 32 Bit registers may be created in the configuration. Each register represents a measured value of one device. This value corresponds with the unique combination of quantity, value and device.

The registers have a unique internal address between 0 and 2,031.

During read out on the Modbus, an offset of **0xC000 HEX / 49,152 DEC** is added to the internal register address.

Because they are 32 Bit registers

- it takes two 16 Bit Modbus registers to be read out. The bit 0 of the address differentiates the high and the low register.
- the internal register address has to be multiplied by 2 for the address calculation of the Modbus address.

The configuration of the adjustable register is described in the chapter “Configuration of the adjustable Modbus registers”.

These registers can be configured either as integer or floating point numbers.

3.3.2 Addresses of the predefined Modbus registers

The measurement values of a sensor can be directly, without configuration, read out via the predefined Modbus registers.

Due to the very large number of metering points, quantities and values, the number of Modbus registers is too large to display all registers in a table.

A scheme is used to calculate Modbus register addresses. There is a scheme for frequency and voltage values and another scheme for the remaining values. This scheme simplifies the calculation of the desired register address.

Following indices are used for the scheme:

Index	Function / quantity
0	Current
1	Active power
2	Apparent power
3	Reactive power
4	COS Phi

5	Voltages and other current-independent values
6	Adjustable registers
7	Unassigned

Scheme for functions 0-4 (current dependent values)

The scheme for these register addresses has been changed with software version V1.06.000 of the base unit.

The interval values of the current dependent values are now device based and require the creation of devices with the register configuration of the ipsensor service tool. The measurements can then be read via the adjustable register addresses.

The schematic register addresses of the values by second of the current dependent values:

Bit 15 – 13	Bit 12 - 5	Bit 4 - 1	Bit 0
Function (0-4)	Sensor - 1	Metering point - 1	H/L Register

The sensors and metering points are indexed. This means that for the register calculation, 1 has to be subtracted from the value of the sensor respectively of the metering point.

The values by second of the current dependent registers are integers.

Structure for function 5 (current independent values)

For this function, the bits 15 – 13 equal the value of 5. The register addresses for this function are described in the table below.

Function	Address
Voltage L1 Mean (Integer)	0xA000 = 40960
Voltage L1 Minimum (Integer)	0xA002 = 40962
Voltage L1 Maximum (Integer)	0xA004 = 40964
Voltage L1 Instantaneous (Integer)	0xA006 = 40966
Voltage L2 Mean (Integer)	0xA008 = 40968
Voltage L2 Minimum (Integer)	0xA00A = 40970
Voltage L2 Maximum (Integer)	0xA00C = 40972

Voltage L2 Instantaneous (Integer)	0xA00E = 40974
Voltage L3 Mean (Integer)	0xA010 = 40976
Voltage L3 Minimum (Integer)	0xA012 = 40978
Voltage L3 Maximum (Integer)	0xA014 = 40980
Voltage L3 Instantaneous (Integer)	0xA016 = 40982
Frequency Mean (Integer)	0xA020 = 40992
Frequency Minimum (Integer)	0xA022 = 40994
Frequency Maximum (Integer)	0xA024 = 40996
Frequency Instantaneous (Integer)	0xA026 = 40998
Line to line voltage L1-L2 Mean (Integer)	0xA080 = 41088
Line to line voltage L1-L2 Minimum (Integer)	0xA082 = 41090
Line to line voltage L1-L2 Maximum (Integer)	0xA084 = 41092
Line to line voltage L1-L2 Instantaneous (Integer)	0xA086 = 41094
Line to line voltage L2-L3 Mean (Integer)	0xA088 = 41096
Line to line voltage L2-L3 Minimum (Integer)	0xA08A = 41098
Line to line voltage L2-L3 Maximum (Integer)	0xA08C = 41100
Line to line voltage L2-L3 Instantaneous (Integer)	0xA08E = 41102
Line to line voltage L3-L1 Mean (Integer)	0xA090 = 41104
Line to line voltage L3-L1 Minimum (Integer)	0xA092 = 41106
Line to line voltage L3-L1 Maximum (Integer)	0xA094 = 41108
Line to line voltage L3-L1 Instantaneous (Integer)	0xA096 = 41110
HW Type	0xB200 = 45568

HW Version	0xB202 = 45570
SW Version 1	0xB204 = 45572
SW Version 2	0xB206 = 45574
SW Version 3	0xB208 = 45576
Status	0xB20A = 45578
Serial number of the base unit	0xB20C = 45580

Scheme for function 6 (adjustable register)

Bit 15 - 13	Bit 12 - 1	Bit 0
Function (6)	Internal register address of adjustable registers Admitted values: 0 - 2031	H/L Register

Examples of predefined register addresses:

Function	Value
Frequency, value by second	0xA026 = 40998
Effective value of voltage L1, value by second	0xA006 = 40966
Effective value of current Value by second Sensor ID 1 Metering point 1	0x0000 = 0
Effective value of current Value by second Sensor ID 2 Metering point 3	0x0024 = 36

4 Glossary

Term	Definition
Quantity	The quantity represents the physical quantity that is being measured, e.g. current, voltage, frequency
Value	The value defines on which base the quantity is calculated: min., max., mean value, value by second
Measurement value	The last read out value of a quantity
Metering point	The part of a sensor which calculates the measurement value of a conductor with current flow.
Phase	1. The voltage phase assigned to a metering point. 2. The terminal on the base where the conductor is connected.
Base	The central device with its software.
Sensor	The devices connected to the base for acquisition of the currents of several conductors with current flow.
Sensor ID	Logical address (ID) to address a sensor on the Sensorbus.
Sensor place	ipsensor provides 10 logical sensor places. By setting an ID within the sensor, the sensor is assigned a place.
Current transformer	1. Toroidal core for conversion of a primary current to a secondary current. One current transformer is used per metering point. 2. External device for conversion of a primary current to a secondary current. These current transformers will be used in a future derivate of ipsensor.
Sensorbus	The cable connecting the base and the sensors with the signals and power supply.
Firmware	Base/sensor loader. This software part cannot be updated in the field.
Software	Base/sensor application. This part of the software can be updated in the field.
Configuration	Data controlling the firmware and the software. These are in part set

	during production, in part during the user and saved in non-volatile memories of the base/sensors.
Register configuration	The configuration part describing the configurable registers. The register configuration can be saved in the metering system and in a file. When saving in the metering system, parts are saved in the sensors and other parts are saved in the base.
Device	This component of the register configuration describes and external device for which defined quantities must be measured. There are single phase and tri-phase devices.
Register	1. This component of the register configuration describes a certain quantity to be gathered by the device and the corresponding address for readout of the quantity. 2. Registers with fix addresses serve to read out defined quantities of individual metering points.
Service Tool	PC software of ipsensor to set parameters.
Metering system	All hardware and embedded software components e.g. Error message: No connection with the metering system possible.
ipsensor	Brand name for all components.
ipsensor Base	Brand name of the base
ipsensor 3/12	Brand name for all sensors with 3 / 12 metering points
ipsensor 12 CT	Brand name for the external sensor (for external current transformers)

5 Technical data

Electrical connections	
Voltage (L1)	230V, 50/60Hz
Power (max. value for base and 10 sensors)	5W
Amperage (min. connection value for the fuse)	1A

Configuration	
ipsensorBase	Up to 10 sensors
Sensors	Versions with 3 and 12 metering points Different amperage
Length of connection via flat ribbon cable (max. value)	5 m

Dimensions ipsensorBase	
Height	91mm
Width	35 mm (2 Modules)
Depth	59 mm

Dimensions sensors	
Height	13 mm
Width	17,5 mm (1 Module) / metering point
Depth	47 mm

Communication interface	
1 x RS485	Modbus RTU, 115,2 kBaud
1 x Ethernet	Modbus TCP, 100 MBit

Metering technique	Nominal value	Preciseness
Voltage measuring	3~230/400 V	Class 1 according to DIN EN 60688
Current measuring	40 A 80 A	Class 1 according to DIN EN 60688
Frequency measuring	50 / 60 Hz	Class 1 according to DIN EN 60688
Power measuring active power	9,2 kW 18,4 kW	Class 1 according to DIN EN 62053-21 (applied[1])

[1] The accuracy of the active power measurement is according to DIN EN 62053-21

The impact of the relevant influencing variables on the measurement accuracy is according to DIN EN 62053-21

6 Safety instructions

The safety and warning instructions here and in further chapters of the manual must be respected to avoid health endangerments, dangerous situations and system damages.

GT elektronik GmbH & Co. KG, is not liable for damages and results due to:

- Connection and / or installation errors.
- Use of violence, damages of the device and / or of the connection leads.
- Damages of the devices due to mechanical influences and / or excess voltage.
- Each and any modification of the device and / or the connection leads.
- Use for other purposes than those described in this manual.
- Exposure to liquids and / or insufficient ventilation.
- Unauthorized opening of the device. This, amongst others, results in warranty loss.
- Consequential damages resulting from non-intended use.

The metering system is laid out for operation under voltages bigger than 50V. These voltages mean life danger due to dangerous body strikes / electric shock.

These safety instructions must be respected:

- Only qualified licensed electricians can carry out works on the electric device.
- Immediate life danger, when touching current leading parts.
- Damages of the insulation or of single components can be life-endangering.
- In case of damaged insulation (housing), the currency supply has to be immediately turned off and the damaged part must be replaced.
- Prior to working on electric devices, switch to not energized and check that there is no current.
- Prior to maintenance, cleaning and repair works, turn off the power supply and secure it against newly turning on.
- Do not override and set out of order any fuse / circuit breaker.
- Protect ipsensor from water.

Conductor cross section for L1, L2, L3 and N	
Solid core	0,5 mm^2 – 1,5 mm^2
Insulation length	10mm
Fine-wired with insulated wire end ferrule	0,5 mm^2 – 1 mm^2

Conductor cross section for A(+), B(-), GND	
Fine-wired with insulated wire end ferrule	0,25mm^2

Environmental conditions	
Storage temperature	-20°C - +65°C
Operation temperature	-20°C - +55°C
Height	max. 2000m over MSL
Humidity	max. 90% non-condensing
Place of operation	Only internal spaces

Safety	
Protection class	II
Installation category	300V CAT III
Contamination level	2

Max. work conditions of voltage input for N entry	
Supply voltage (L1)	230V +/- 10%
Metering voltage (L2, L3)	0 – 230V + 10%

Max. work conditions of voltage inputs	
Current measurement	0 – I_{Nenn} + 10%

Max. work conditions of RS485 interface
Stated under norm ANSI/TIA/EIA-485-A-98

Max. work conditions for Ethernet interface
Stated under norm IEEE 802.3 Clause 25 und TIA-568A/B

Max. work conditions for Sensorbus interface
This proprietary interface must only be used to connect with sensors in the ipsensor metering system.

	The voltage entries L1, L2, L3 must be secured by 1A, release characteristic B circuit breakers. A method has to be provided, to switch the device volt-free, e.g. a distinctly marked interrupter.
	The installation of the sensors, the flat ribbon cable and the base has to be done behind a cover panel and in such a way to ensure that only qualified licensed electricians can access the sensors, the flat ribbon cable and the connecting terminals without removing the cover panel. The cover panel has to be clearly

	marked that open, dangerous, current leading parts are behind the panel. Alternatively, all components of iPSensor can be installed in such a way that only qualified licensed electricians can access them (e.g. electric control cabinet).
	A minimum distance of the flat ribbon cable to the current leading parts of the device must be respected. The blank ends of the flat ribbon cable must be closed by a shrink hose.
	Protection class II Touch protection is guaranteed by a protective insulation.

7 Declaration of conformity

Manufacturer: GT elektronik GmbH & Co. KG

Sauerzapfstraße 14

D - 92507 Nabburg

Phone +49 / (0) 9433 / 24 13-0

Fax +49 / (0) 9433 / 24 13 99

E-Mail info@gt-elektronik.de

Declares that the product ipsensor is conform to the European directive

Low voltage directive 2014/35/EU

Proven through compliance with the following standards:

	Norm	Datum
Radio disturbance characteristics	55022 Class B EN 61000-6-3 EN 61000-6-4	2010 + AC 2011 2007 + A1 2001 2007 + A1 2001
Interference immunity	EN 61000-6-1 EN 61000-6-2	2007 2007
Harmonic currents	EN 61000-3-2	2006 + A1 2009 + A2 2009
Voltage fluctuations	EN 61000-3-3	2008
Static electrical discharge	EN 61000-4-2	1995 + A1 1998 +A2 2001

High frequency electromagnetic fields	EN 61000-4-3	2006
Fast transient bursts	EN 61000-4-4	2004
Conducted disturbances	EN 61000-4-6	1996 + A1 2001
Power frequency magnetic field	EN 61000-4-8	1993 + A1 2001
Voltage dips	EN 61000-4-11	2004
Overvoltages, CAT III	IEC 61010-1	2010
General safety regulations	IEC 61010-1	2010

Signed in the name of GT elektronik GmbH & Co. KG

Appendix A Basis of calculation by EN 61557-12:2008

A.1 Active power ($\boldsymbol{P}$) and active energy ($\boldsymbol{E_a}$)

A.1.1 Second values

The second values of the active power P_p from the phase conductor with the phase p are defined by

$$P_p := \frac{1}{T}\int_0^T v_p(t) \cdot i_p(t)\, dt$$

with:

- the sampling value of the voltage $v_p(t)$ from the neutral conductor against the phase conductor with the phase p at the time t,
- the sampling value of the current $i_p(t)$ from the phase conductor p at the time t and
- the integration time T with $T = 1s$.

The values for the active energy E_a are calculated by the product of the corresponding active power with the integration time.

A.1.2 Single phase values

The mean value $\overline{P_p}$ is defined by

$$\overline{P_p} := \frac{1}{T}\int_0^T P_p(t)\, dt$$

with T as the integration time, that was configured in the register configuration. The minimum / maximum value is represented by the smallest / largest second value during that time.

A.1.3 Three phase values

The three phase second values P, as well as the mean values $\bar{P}$, are calculated from the single phase values by

$$P := P_1 + P_2 + P_3$$

and

$$\bar{P} := \overline{P_1} + \overline{P_2} + \overline{P_3}$$

The maximum and minimum are represented by the largest and smallest three phase second value during the integration time.

A.2 Idle power ($\boldsymbol{Q}$)

A.2.1 Second values

The second values of the idle power Q_p from the phase conductor with the phase p are defined by

$$Q_p := \sqrt{{S_p}^2 - {P_p}^2}$$

with:

- the apparent power S_p for the phase conductor p and
- the active power P_p for the phase conductor p.

A.2.2 Single phase values

The mean value $\overline{Q_p}$ is defined by

$$\overline{Q_p} := \sqrt{\overline{S_p}^2 - \overline{P_p}^2}$$

The minimum / maximum is represented by the smallest / largest second value during the integration time T.

A.2.3 Three phase values

The three phase second values Q_A, as well as the mean values $\overline{Q_A}$, are calculated arithmetically from the three phase values of the active and apparent power by

$$Q_A := \sqrt{S^2 - P^2}$$

and

$$\overline{Q_A} := \sqrt{\bar{S}^2 - \bar{P}^2}$$

The maximum and minimum are represented by the largest and smallest three phase second value during the integration time.

A.3 Apparent power ($\boldsymbol{S}$)

A.3.1 Second values

The second values of the apparent power S_p from the phase conductor p are defined by

$$S_p := V_{pN} \cdot I_p$$

with:

- the effective L_p-N- voltage V_{pN} and

- the effective value of the current I_p from phase conductor p.

A.3.2 Single phase values

The mean value $\overline{S_p}$ is defined by

$$\overline{S_p} := \overline{V_{pN}} \cdot \overline{I_p}$$

The minimum / maximum is represented by the smallest / largest second value during the integration time T.

A.3.3 Three phase values

The three phase second values S_A, as well as the mean values $\overline{S_A}$, are calculated arithmetically from the single phase values by

$$S_A := S_1 + S_2 + S_3$$

and

$$\overline{S_A} := \overline{S_1} + \overline{S_2} + \overline{S_3}$$

The maximum and minimum are represented by the largest and smallest three phase second value during the integration time.

A.4 Current (*I*)

A.4.1 Second values

The second values of the current I_p from the phase conductor with the phase p are defined by

$$I_p := \sqrt{\frac{1}{T}\int_0^T \left(i_p(t)\right)^2 \, dt}$$

with $T = 1s$ ist.

A.4.2 Single phase values

The mean value $\overline{I_p}$ is defined by

$$\overline{I_p} := \frac{1}{T}\int_0^T I_p(t)\, dt$$

with T as the integration time, that was configured in the register configuration. The minimum / maximum value is represented by the smallest / largest second value during that time.

A.4.3 Three phase values

The three phase second values I, as well as the mean values $\bar{I}$, are calculated arithmetically from the single phase values by

$$I := \frac{I_1 + I_2 + I_3}{3}$$

and

$$\bar{I} := \frac{\overline{I_1} + \overline{I_2} + \overline{I_3}}{3}$$

The maximum and minimum are represented by the largest and smallest current that was measured in one of the phase conductors.

A.5 Voltage ($\boldsymbol{U}$)

A.5.1 Second and mean values L_p-N

The second values of the voltage V_{pN} between the phase conductor p and the neutral conductor are defined by

$$V_{pN} := \sqrt{\frac{1}{T}\int_0^T \left(v_{pN}(t)\right)^2 \, dt}$$

with $T = 1s$. The mean value $\overline{V_{pN}}$ is calculated from

$$\overline{V_{pN}} := \frac{1}{T}\int_0^T V_{pN}(t) \, dt$$

with T as the integration time, that was configured in the register configuration. The minimum / maximum value is represented by the smallest / largest second value during that time.

A.5.2 Second and mean values L_p-L_g

The second values of the voltage U_{pg} between the phase conductor p and the phase conductor g are defined by

$$U_{pg} := \sqrt{\frac{1}{T}\int_0^T \left(v_{gN}(t) - v_{pN}(t)\right)^2 \, dt}$$

with $T = 1s$. The mean value $\overline{U_{pg}}$ is calculated from

$$\overline{U_{pg}} := \frac{1}{T}\int_0^T U_{pg}(t)\,dt$$

with T as the integration time, that was configured in the register configuration. The minimum / maximum value is represented by the smallest / largest second value during that time.

A.6 Power factor

A.6.1 Second values

The second values of the power factor PF_p from the phase conductor p are defined by

$$PF_p := \frac{P_p}{S_p}$$

A.6.2 Single phase values

The mean values $\overline{PF_p}$ are defined by

$$\overline{PF_p} := \frac{\overline{P_p}}{\overline{S_p}}$$

The minimum / maximum value is represented by the smallest / largest second value during the integration time T.

A.6.3 Three phase values

The three phase second values PF_A, as well as the mean values $\overline{PF_A}$, are calculated arithmetically from the three phase values of the active and apparent power by

$$PF_A := \frac{P}{S_A}$$

and

$$\overline{PF_A} := \frac{\overline{P}}{\overline{S_A}}$$

The maximum and minimum are represented by the largest and smallest three phase second value during the integration time.