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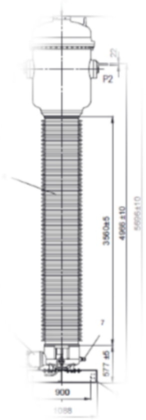
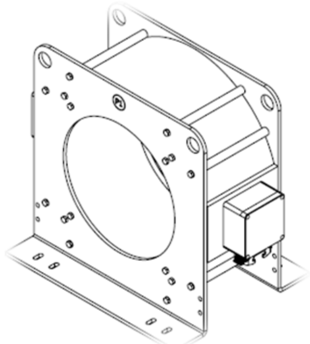
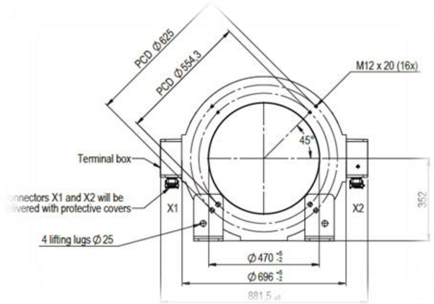
A Phoenix Mecano Company







User manual

HITACC

HVDC Zero-flux^{TM}-current measuring system

Version: For 3U high electronics module

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User manual

Zero-flux™ current measuring system

System **HITACC** as applied for

High Voltage DC (HVDC)

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PM Special Measuring Systems B.V. operates a policy of continuous development and improvement. PM Special Measuring Systems B.V. reserves the right to change the contents of this manual without prior notice.

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1. INTRODUCTION

The bipolar Zero-flux™ current transformer system HITACC, developed by PM Special Measuring Systems for HVDC applications, epitomize the concept of a galvanically insulated system for measurement of direct and alternating currents up to 6 kA (continuously) with very high accuracy and stability.

Whilst designing the measuring system HITACC, special attention is paid to reliability, measuring high over currents, withstanding short circuit currents, insulation levels, immunity to electromagnetic and ambient disturbances, long distance between measuring head and electronics module and abnormal situations like auxiliary supply failures.

1.1 The basic principle

The primary current I_P generates a magnetic flux that will be counteracted by the current I_S in the secondary winding (N_S) of the measuring head. Any remaining flux is sensed by three toroidal-wound ring cores located within the secondary winding volume.

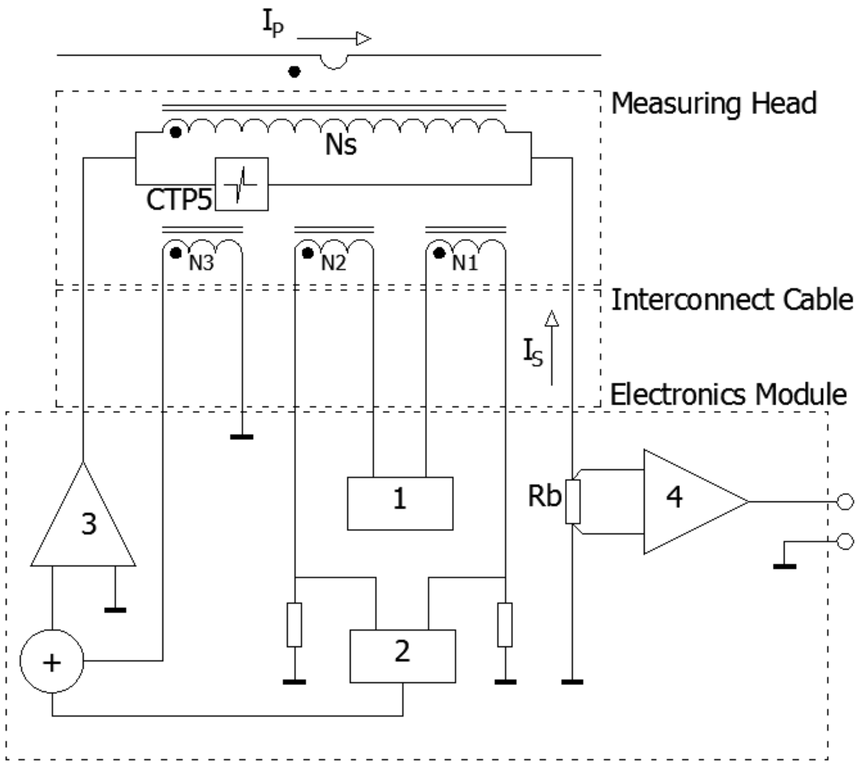


Fig. 1.1.a Basic diagram of the Zero-flux current transformer with voltage output

Two cores (N_1, N_2) are used to sense the DC part of the remaining flux. The third core N_3 senses the AC part. The CTP5 protects the measuring head. Refer also to sub clause 1.7 for more details.

An oscillator (1) drives the two DC-flux sensing cores into saturation in opposite direction. The resulting current peaks are equal in both directions if the remaining DC-flux is zero. If not, their difference is proportional to the residual DC-flux. The HITACC has a double peak detector (2) to determine this DC-flux. After adding the AC component (N_3) a control loop is set up to generate the secondary current that makes the flux zero. A power amplifier (3) with high over current capability provides this secondary current to N_S, which normally has 2000 turns. The secondary current, which is a fractional image of the primary current, is fed to a burden resistor (R_b) to convert the signal into a voltage. The signal across the burden is amplified to make the signal available for further use, by means of a precision amplifier (4). The described principle makes it possible to measure DC and AC currents as well.

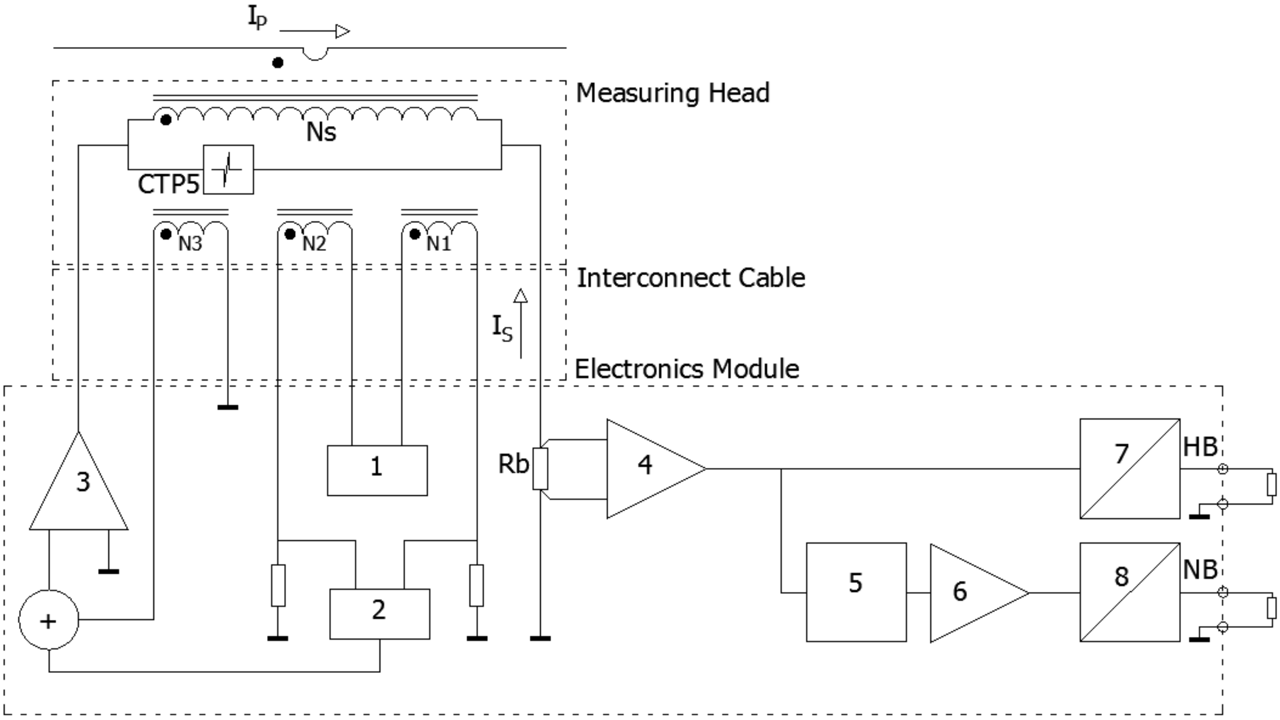


Fig. 1.1.b Basic diagram of the Zero-flux current transformer with current output

The HITACC can also be provided with a current output. Than the output voltage from the precision amplifier (4) is converted with a voltage to current amplifier (7) into a current with the same high bandwidth. This output is called "HB-output" where HB is high bandwidth.

A narrow bandwidth or "NB-output" can be provided in order to find a small DC-current out of a large AC-current. In that case the signal from the precision amplifier enters a low-pass filter (5) and is amplified (6) to the level as required for a second voltage to current converter (8). This channel forms the so called NB (narrow bandwidth) output and has a bandwidth of DC tot approximately 8 Hz.

Note: The NB-option also is available for a voltage output.

The unique design of the HITACC system provides high accuracy and stability without the need for temperature control devices.

Above several kHz the power amplifier (3) does not have active control over its output current but merely forms a short circuit. The HITACC still performs as a wideband current measuring device with the measuring head acting as a passive current transformer.

The bandwidth of the HITACC Current Measuring System is limited by the stray reactance and capacitance in the measuring head and interconnecting cable. The actual bandwidth in practice is determined by filter settings of the precision amplifier.

Relay contacts for the internal supply voltages and proper working of the electronics indicate the status of the HITACC measuring system.

1.2 The burden resistor

The burden resistor in most cases is made of a highly stable resistance alloy. A special coating will contribute to a good long-term stability. This resistance wire is fold-up to create a low inductance. For accurate measurement, voltage taps are applied leading to the precision amplifier. The TC is <10 ppm / K. The absolute resistance value depends on the rated current, the specified ratio and the gain of the precision amplifier. The wire diameter as used depends on the secondary current level.

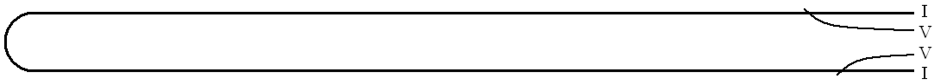


Fig. 1.2 Construction of the burden resistor

1.3 The precision amplifier

The precision amplifier is a very stable differential amplifier, which delivers a highly accurate output voltage, proportional to the secondary current through the burden resistor. To ensure that the gain factor remains constant, the most important point is that the temperature coefficients of the gain-setting resistors are matched (TC tracking). The offset error is minimized by careful choice of the operational amplifier and fine-tuned in our factory. The gain will be coarse and fine adjusted in order to compensate for tolerances in burden and gain-setting resistors. The output may be loaded up to 10 mA.

1.4 Voltage to current converter

The voltage to current converter is a high precision and very stable trans-admittance amplifier able to deliver 200 mA (DC or AC) into a load of typical 2 Ω (max. load is 12 Ω). The nominal transfer ratio of the voltage to current converter is 2 V / 100 mA. Accuracy of the output current is established by selecting highly accurate and reliable components for current sensing and feedback. Offset error, common mode rejection and gain are factory adjusted. The output of the precision amplifier is connected to the input of the voltage to current converter for full bandwidth applications and is also connected to the low pass channel if applicable.

1.5 Normalizing

The primary rated current can be as high as 4 kA typical. The output voltage at rated current will be as defined by the customer, but normally it is 2 V. In that way it is possible to measure overload currents up to 300 % (6 V) and transient currents up to 600 % (12 V). If measuring AC, 12 V is the max. peak value for the waveform.
Example in case of a voltage output: At a rated current of 1600 A the secondary current is 0.8 A. This current creates 0.2 V when flowing through a burden resistor of 0.25 Ω. With a gain of 10 for the precision amplifier, the output produces 2 V at 1600 A. If a higher output signal is demanded, the length of the burden wire will be changed and/or the gain will be made 20. The same explanation applies for other rated currents.

Example in case of a current output: At a rated current of 3000 A the compensation current is 1.5 A. At 1.5 A the burden in combination with the precision amplifier produces 2 V. The voltage to current converter for the HB-channel than provides 100 mA to the output. If a NB-channel is involved this may produce for example 100 mA at a DC-current of 50 A when the gain after the low-pass filter is set at 60. The HB-output and the NB output as well can handle an overload of 200 %.

1.6 Application

HVDC measuring heads are often placed outdoors and therefore resin casted. The measuring head internally has a magnetic shield to prevent the three sensing cores for saturation due to external magnetic fields caused by nearby current carrying conductors or air coils. Further the head internally is surrounded completely with a copper foil screen that forms a faraday cage.

The bore is large to carry a bushing or to put around a wall bushing in case of high primary voltages. Several sizes of casted heads are available, but also non-casted heads for oil-insulated applications.

The terminal box includes a robust 32-pole industrial connector. The measuring head is protected by a CTP5 protection device which is placed inside the terminal box. (See also sub clause 1.7)

The electronics module for HVDC is equipped with over-voltage arresters and EMC filters to meet stringent immunity standards, although the electronics module is normally placed in a control room with a controlled EM-climate.

The electronics module can be fed from an unipolar supply source. A built-in DC-DC converter creates the internal ±24 Vdc supply. This DC-DC converter also galvanically separates the output signal(s) from the supply source. Input diodes are fitted for connecting a second supply system with the same common return. As an option a redundant power supply (galvanically separated from the main power supply) can be mounted in the electronics module also.

Fig. 1.6 H059D with L-support

Another option is feeding the electronics module with +24 Vdc / 0 / -24 Vdc directly. In that case no DC-DC converter is installed. Then the output signals are galvanically not separated from the feeding 0 V-rail.

1.7 Protective device CTP5

Standard, all measuring heads delivered since January 2015 will be provided with a protective device. The CTP5 protects the measuring head in case a primary current is applied whilst the electrical connection between measuring head and electronics module is interrupted. Without this protective device it could lead in such a case to very high voltages at the windings which in turn could lead to a failure in the measuring head. This risk is most applicable in case of an alternating current. In normal operating conditions the CTP5 is not active and does not have any influence to operation and accuracy of the system. The CTP5 is mounted in parallel to N4 in the connecting box of the measuring head. By protecting N4 all windings are protected at the same time. If the CTP5 is active an audible noise may be produced by the measuring head. This is not harmful. This sound will cease as soon the connection is re-established, in absence of a primary current or if a short circuit connector is connected.

The short circuit connector is not a part of standard delivery and can be ordered separately.
Part number ZF16017.

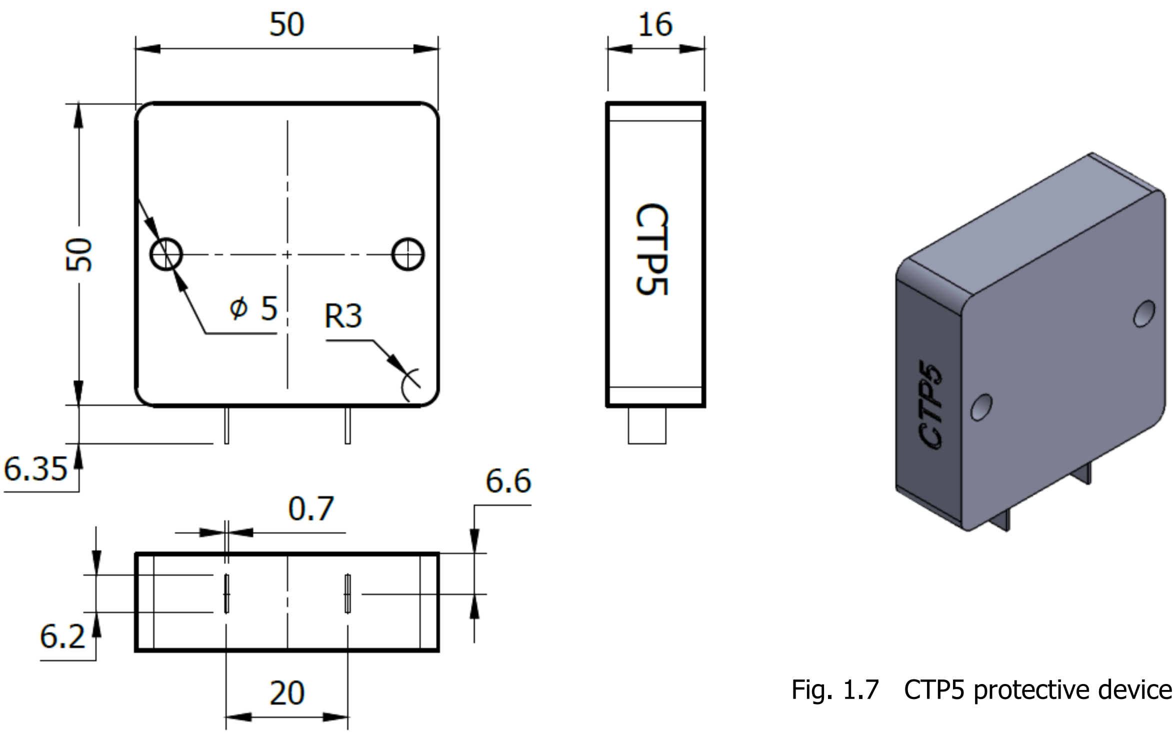


Fig. 1.7 CTP5 protective device

In case of non-encapsulated measuring heads the CTP5 will be delivered separately and must be installed by the customer.

WARNING:
It is prohibitted to pull the plug at the measuring head! Voltage spikes in a range of 300Vp are present at the pins of the measuring head when not connected and alternating primary current is present.

If an electronics module must be exchanged for any reason it is allowed to pull plug X2 at the electronics module. However, the responsibility for pulling out plug X2 lies with the user ! The risk level is low if the plug on the EM-side is disconnected. The exchange procedure should be kept as short as possible and must be performed by certified personel only !

1.8 Dynamic range

The unique advantage of the HITACC Current Measuring System is that very large and very small currents can be measured at high accuracy. The wide dynamic range (for both polarities) can be divided into three parts:

- Part one: defined by the end user as nominal and ends at 1 pu (per-unit);
- Part two: is up to the current where the compensating amplifier is current-limited;
- Part three: is where the excess secondary current is diverted into a bypass network to prevent high dissipation in the power amplifier. In this mode, the measuring head acts like a traditional current transformer that, starting from zero flux, builds up flux (and error) until the core saturates.

  The second part usually ends at approximately 3 pu. In the third part a single peak of 6 pu and 20 ms wide still can be measured with 1 % accuracy. Much higher and wider surges are handled without damage, but the voltage output clamps at 12.5 V respectively at 300 mA in case of a current output. In case the core saturates, the zero flux condition is lost, and a search cycle is started automatically. This means the secondary current is swept between the minus and plus current limits in a slow triangle until zero flux is detected, and normal tracking continues. The same happens when the auxiliary power is switched-on with (high) primary current present. Saturation will be indicated through the 'Output valid' contact that is actively closed under normal working conditions. If required, multiple analog outputs can be delivered.

1.8.1 Example in case of voltage outputs

The main output provides 2 V at the 1 pu current and covers the second and third part of the dynamic range. An extra output provides 10 V at the 1 pu current having the same bandwidth as the main output. Both outputs provide a wide-band copy of the primary current. They both are clamped at approximately 12.5 V.

Especially for FACTS applications, another type of extra output is used. The extra output e.g. is 100 times more sensitive with a sharp cut-off filter from DC - 8 Hz to detect a small DC component in a high AC current. Applications are balance control in thyristor controlled reactors and detection of geomagnetic induced current in long overhead HV lines.

1.8.2 Example in case of current outputs

The High Bandwidth (HB) output provides 100 mA at 3000 A_{AC}. The Narrow Bandwidth (NB) output provides 100 mA at 50 A_{DC} (if DC current is present in the primary circuit). Both outputs can measure accurately twice the mentioned current levels. The output clamping level approximately is 300 mA_{PK}.

Note: The HB output is able to measure 6000 A_{DC}. Output NB than will be clamped to approximately 300 mA, in case the primary DC current is > 150 A.

1.9 Back-feed protection for the power circuit

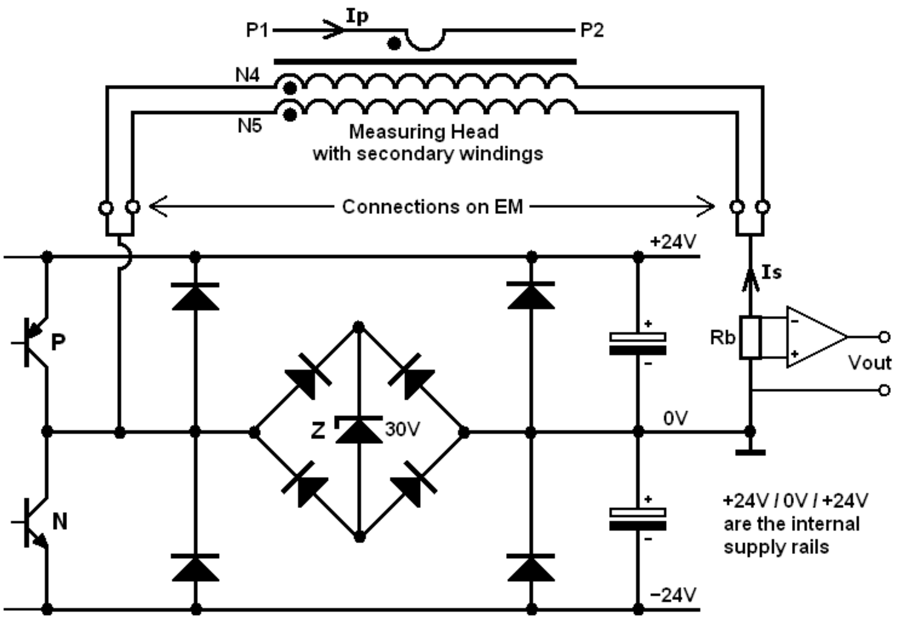


Fig. 1.9 Power circuit of HITACC module

The HITACC-module is well protected against back-feed energy from the measuring head. The main components to protect for back-feed are the free-wheeling diodes across the transistor power stages and the rectifier bridge with power-zener stage. This Z-stage can dissipate up to 100 W continuously.

When the primary current cannot be actively compensated anymore, back-feed can arise. Reasons for back-feed can be current limitation of power stages P and N, or lack of supply voltage in the secondary circuit due to excessive voltage losses in power stage, cable, measuring head and burden at high currents or supply failure.

Up to 10 kA (50 or 60 Hz) the free-wheeling diodes or Z-stage will not be active and will be handled by the P-stage, N-stage and the measuring head.

Primary current pulses (positive or negative) of more than 10 kA and sufficient pulse length can make Z-stage acting. In that case, the voltage on one of the buffer capacitors will rise until the Z-stage limits this voltage to approx. 35 V, taking over the secondary current. Pulsed currents of 50 kA or more are controlled also this way. Roughly 30 ms after a 50 kA pulse, the measuring head saturates and the energy transfer to the secondary circuit will decay to zero. The magnetic design of the head, but also the pulsed current level and cable length (resistance), determines the saturation time.

If saturation occurs, this will be signaled by a relay contact 'Output valid' changing from closed state to open state. The so called 'Fast valid' signal (open collector) will indicate an incipient saturation of the measuring head but will not necessarily be followed by a change of state of the 'Output valid' relay.

Back-feed also can occur when the supply voltage fails and current (AC or DC) is flowing or starts flowing in the primary circuit. In that case the measuring head behaves as a traditional current transformer. AC-current will be transformed to the secondary circuit and P/N start conducting, limiting the voltage on the buffer capacitors. AC-currents up to at least 10 kA can be handled without problems. Even if P/N broke down for some reason, the voltage on the capacitors is limited to +35 V and –35 V. The power circuit effectively absorbs primary current pulses up to at least 50 kA. Pulses higher than approx. 10 kA make the Z-stage acting. This is more or less the same behavior as with supply voltage on.

1.10 Galvanic insulation

Measuring head

For HV insulation, the measuring head is provided with a bushing, installed around a HVDC cable, fixed around a gas-insulated conductor (SF6) or mounted inside a freestanding insulator. Measuring heads can be placed indoors or outdoors.

Special interconnect cable

The special interconnect cable between the measuring head and electronics module can be as long as 300 m. If a cable length longer than 300 m is required the manufacturer must be consulted. The special cable consists of 7 pairs galvanically separated from the outer screen. Insulation voltage between outer screen and pair screens inside is 3 kV 50 Hz 1 min. For further information please observe cable specific document ZF02.377.

Electronics module

The yellow color represents the insulation barriers between the functional blocks of the HITACC electronics module. The red block represents the metal chassis. For test levels between the blocks and chassis see sub clause 2.9 in this manual.

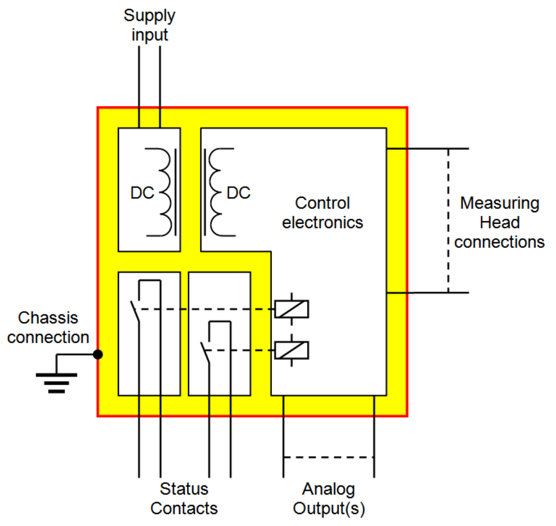


Fig. 1.10 Galvanic insulation zones of the HITACC electronics module

NOTE: For supply option +24 Vdc / 0 / -24 Vdc the supply input is galvanically connected with the analog outputs.

1.11 EMI topology for standard cable RE-02YS(st)HCWBH-fl-PiMF 7x2x1.5 mm^2

The EMI topology regarding the connection of electronics module and measuring head is shown in the model below.

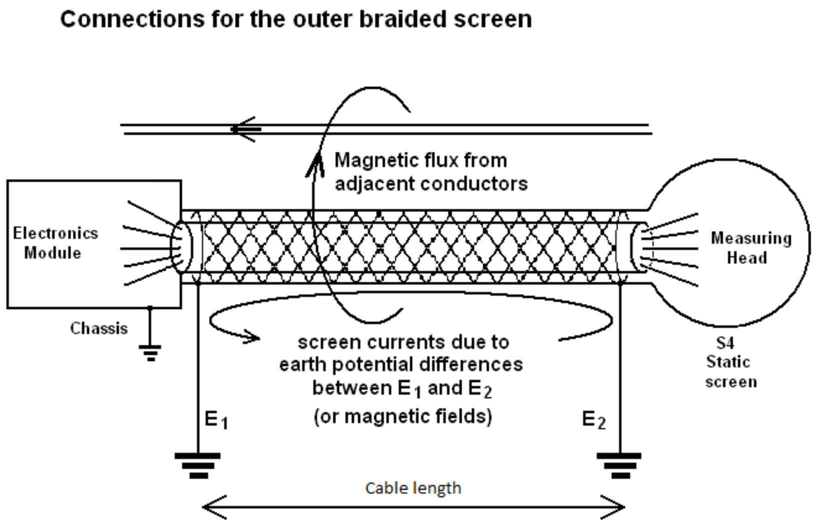


Fig. 1.11 Basic earthing connections

Stray magnetic fields from adjacent (AC) current carrying conductors may induce a current in the cable from measuring head to the electronics module. This current will flow in the braided screen, which must be connected to ground on the electronics module and the measuring head as well.

The braided outer screen is best connected to earth (E1) at the electronics cabinet entrance. The far end of the braided screen is connected to local ground (E2).

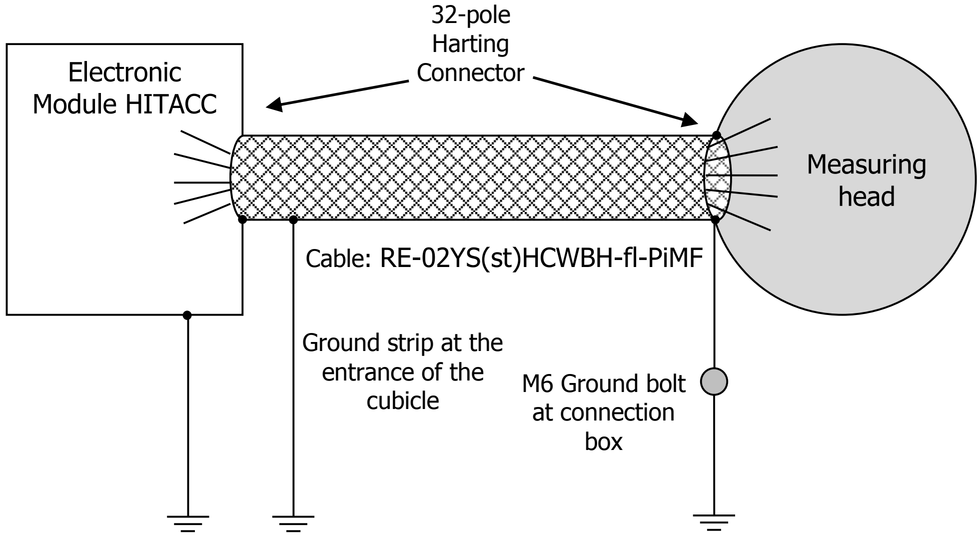


Fig. 1.12 Connection in practice

Please refer to Appendix II of this manual for detailed cable information.

2. TECHNICAL SPECIFICATIONS for a standard HITACC system

Each HITACC current measuring system can be provided with voltage or current outputs or both. Standard specifications are summarized below. Please refer to project specific specifications for the actual figures.

2.1 Measurement characteristics of the measuring function

(for the specified operating temperature range)

Primary rated current I_N (bipolar DC or AC)	Up to 4 kA	(see rating plate on MH)
Overload, continuously	1.25 pu	
Overload, non-saturating	3 pu	(max. 5 s)
Overload transient, measurable	6 pu	(30 ms)
Dynamic peak current	50 kA	
Time to saturation for dynamic peak current >3pu	20…50 ms	(indicated by "output valid" contact)
Rated output voltage (at 1 pu)	2 V	(see rating plate on EM)
Output signal clipping level (with 1 kΩ load)	12.5 V	(max. 14 V unloaded)
Output load current	10 mA	
Output ripple (rms)	1 mV	(observed for 0…10 kHz)
Accuracy for DC/AC (see notes 1 … 4)	0.05 %	(at 1.25 pu)
Bandwidth, -3 dB (see note 2)	10 kHz	
Tracking error (see note 3)	15 µs	
AC-amplitude error (see note 4)	$0.4 \cdot f^2$ (%)	(f in kHz)
Phase error (see note 3)	$5.4 \cdot f$ (°)	(f in kHz)
Step response rise/fall time (see note 5)	< 100 µs	(to reach 90 % level)
Step response settling time (see note 5)	< 1 ms	(for error within 1 %)
Output slewing rate	> 1 V/µs	(feature of applied Op-Amp)

Note 1: A general formula for the static error for 0 to 3 pu is (in A): $0.5(I_P^2/I_N) + 0.1$ (I_P and I_N in kA)

Note 2: I_P 100 % amplitude for 0…500 Hz. De-rate I_P inversely proportional to 5 % at 10 kHz and above

Note 3: The dynamic response of a standard HITACC system matches very well with a low-pass first-order network with a time constant of 15 µs. Therefore the phase error (in °) is: $5.4 \cdot f$ (f in kHz)

Note 4: Add the accuracy figure to the AC-amplitude error to find the total AC error

Note 5: The theoretical rise/fall time is 35 µs and the settling time to 1 % error is ~75 µs (5 τ).
However, this is hard to demonstrate because an infinite steep current step is impossible to realize

2.2 Measurement characteristics current output (HB)

(for the specified operating temperature range)

Primary rated current I_N (bipolar DC or AC)	According rating plate (bipolar DC or AC)
Overload, continuously	1.25 pu
Overload measurable	2 pu (max. crest value AC: 3 pu)
Overload transient, non-saturating internally	6 pu (30 ms)
Dynamic peak current	50 kA (max.)
Time to saturation for dynamic peak current >3 pu	30…50 ms (indicated by "output valid" contact)
Output transfer ratio	200 mA (at I_p = 6000 A)
Output signal clipping level (with 12 Ω load)	300 mA (max. 320 mA with 0 Ω)
Output compliance voltage	3.6 V (peak)
Output ripple and noise (rms)	≤ 0.1 % (of nominal output current)
DC-offset	≤ 0.02 % (of nominal output current)
DC-accuracy (up to 2 pu)	≤ 0.1 % (of actual current)
Bandwidth, -3 dB (see note 1)	DC…30 kHz
AC-amplitude error (see note 2)	$0.2 \cdot f^2$ (%) (f in kHz)
Step response rise/fall time (see note 3)	< 10 µs (from 10 % to 90 % level)
Tracking delay time (see note 3)	< 5 µs
Step response settling time (see note 3)	< 20 µs (for error within 10 %)
Step response settling time (see note 3)	< 1 ms (for error within 1 %)
Output slewing rate	> 20 A/ms

Note 1: I_P 100 % amplitude for 0…500 Hz. De-rate I_P inversely proportional to 5 % at 10 kHz and higher

Note 2: Add the DC-accuracy figure to the AC-amplitude error to find the total AC error

Note 3: The specified rise/fall time, delay time, settling time and output slewing rate are hard to demonstrate because an infinite steep primary current step is impossible to realize

Abbreviations:

I_N : Nominal current, also indicated with 1 pu (pu means "per unit")
I_P : Primary current, actual primary current flow
MH : Measuring Head
EM : Electronics Module
N.A. : Not Applicable

2.3 Measurement characteristics current output (NB)

(for the specified operating temperature range)

Primary DC current range (measurable)	Acc. Rating plate (I_N is superimposed with AC-current)	
Output transfer ratio (for DC)	200 mA	(at 100 Adc)
Output signal clipping level (with 12 Ω load)	300 mA	(max. 320 mA at 0 Ω)
Output compliance voltage	3.6 V	(peak)
Output ripple (rms, referred to primary DC range)	≤0.1 %	(observed for 0…10 kHz)
DC-accuracy (I_p superimposed with 1500 A_{RMS} / 50 Hz)	≤0.2 %	(of 200 mA, being ±0.4 mA)
Bandwidth, -3 dB	DC…8 Hz	
Attenuation for primary current with f = 50 Hz	80 dB	(90 dB for 60 Hz)
Step response rise / fall time	<300 ms	(to reach 90 % level)
Step response settling time	<1 s	(for error within 1 %)

Abbreviations:

I_N : Nominal current, also indicated with 1 pu (pu means "per unit")
I_P : Primary current, actual primary current flow
MH : Measuring Head
EM : Electronics Module
N.A. : Not Applicable

2.4 Operational characteristics

Return bar: distance to head surface	1 m	
Centre bar: minimum distance to the bend	1 m	
Centre bar: radial displacement sensitivity	< 0.01 %	(if 10 cm out of central axis)
Max. external magnetic DC-field	3 mT	(equals 2387 A / m)
Max. external magnetic AC-field (50/60 Hz)	1.25 mT	(equals 1000 A / m)
Minimum separation between heads	Nil	
Stabilization time after initial switch-on	< 2 s	(I_P ≤ 1 pu)
Stabilization time after saturation	< 2 s	(after I_P has returned to ≤ 1 pu)
Cable length: head to electronics	< 300 m[1)]	(length specified by user)

1) Always consult the manufacturer if a cable longer than 300 m is required. (Maximum length depends of the number of pairs of the interconnection cable and the requested dynamic behavior

2.5 Environmental characteristics

EMC	IEC61000-series
Operating temperature range: electronics	0 to +55 ºC
Operating temperature range: measuring head	–20 to +70 ºC
Relative humidity (RH): electronics	Up to 95 % (non-condensing)
Storage temperature range	–20 to +55 ºC
Temperature rise of measuring head (windings)	< 5 K (at 1 pu)

2.6 Measuring head physical characteristics

Marking: identification	Manufacturer, type, ser. number and nom. current
Marking: direction of positive current	P1 and P2 (output signal electronics module positive if I_P enters at P1)
Dimensions, fixings and weight	See drawings
Shielding	Magnetic shield and electrostatic foil screen
Connection method for interconnection cable	M5 studs, brass (inside connection box) alternative: 32-pole industrial connector
Earthing connection (LE = local earth)	M6 stud (on connection box)
Interconnection cable: type	Twisted and screened pairs, overall screen

2.7 Measuring head electrical characteristics

Rated primary current I_N	Any level up to 4 kA
Induced voltage into primary bar	< 5 mV_{PP}
Insulation sec.: inter-winding, windings-screens	> 100 MΩ @ 500 V_{DC}
Insulation: primary to secondary	Dependent from primary insulator
Test voltage sec.: inter-winding, windings-screens	3 kV_{RMS}, 50 Hz, 1 min
Inter-turn over-voltage test for N_4 and N_5	4.5 kV_{PEAK} (by making high 50 Hz primary current)
Test voltage: primary to secondary	Dependent from primary insulator

2.8 Electronics module physical characteristics

Marking: identification	Manufacturer, type, serial number and weight
Marking: transfer ratio(s) and supply voltage	On rear panel
Dimensions (W x H) and fixing	3U x 19 inch rack mounting (see drawings)
Weight	8.5 kg
Cooling	Natural (vent slots in bottom / top cover)
Connection method Standard: 3 connectors (supply, MH and outputs) Alternative: terminals, screw type, with slides	 Type Han10A, Han32E and Han16A (make Harting) Type URTK/S-BEN 0.5 – 10 mm^2 (make Phoenix Contact)

Note: 1U equals 1¾ inch or 44.45 mm (1 inch = 25.4 mm)

2.9 Electronics module electrical characteristics

Supply options: Bipolar ±24 V_{DC} Unipolar 24 V_{DC} (built-in DC-DC converter) Unipolar 48 V_{DC} (built-in DC-DC converter) Unipolar 120 V_{DC} (built-in DC-DC converter) Unipolar 240 V_{DC} (built-in DC-DC converter)	Input supply range: ±21 … ±32 V_{DC} (no galvanic isolation) 18 … 32 V_{DC} (with galvanic isolation) 36 … 64 V_{DC} (with galvanic isolation) 90 … 156 V_{DC} (with galvanic isolation) 180 … 312 V_{DC} (with galvanic isolation)
Inrush current (per DC-DC converter installed): Option bipolar ±24 V_{DC} Option unipolar 24 V_{DC} Option unipolar 48 V_{DC} Option unipolar 120 V_{DC} Option unipolar 240 V_{DC}	Width < 50 ms Recommended rating CB (C-curve) ±20 A_{PEAK} 10 A 20 A_{PEAK} 10 A 10 A_{PEAK} 5 A 4 A_{PEAK} 2 A 2 A_{PEAK} 1 A
Supply redundancy	Two inputs (OR-diodes) with separated return for feeding from two battery systems.
Power consumption (in case of 2 DC-DC converters add 15 W)	15•(I_P + 1) W (I_P in kA, max. 10 kA) (for a bipolar supply, the pos. half **or** the neg. half will be loaded depending of the direction of I_P)
Status contacts: general description	Isolated contacts. Closed when working properly Contact rating 100 V / 1 A / 10 VA All status contacts will indicate FALSE (open) when the electronics module is not powered
Status contact: Supply OK	CLOSED when internal supply voltage of the Current Measuring System is beyond ±21 V
Status contact: Output valid	CLOSED if no fault conditions are detected, indicating that the analog output is valid
Status signal: Fast valid Output type: open collector with 100 Ω in series	CONDUCTING if no fault conditions are detected, indicating proper internal operation Rating: max. +30 V_{DC} / 50 mA
Insulation all electronics circuits to chassis	> 100 MΩ @ 500 V_{DC}
Test voltage all electronics circuits to chassis	2.5 kV_{RMS} / 50 Hz / 1 min [1)]
Test voltage supply input to rest of electronics	2.5 kV_{RMS} / 50 Hz / 1 min [1)] [2)]
Test voltage status contacts to rest of electronics	2.5 kV_{RMS} / 50 Hz / 1 min
Test voltage between status contacts	1.0 kV_{RMS} / 50 Hz / 1 min

Remark:
Specifications in project related documents are superior to the specifications as listed above.

1) 3 kV_{RMS} on request
2) Not applicable for bipolar supply

3. INSTALLATION

Both the electronics module and the measuring head have a unique rating plate for easy identification. Electronics module, interconnect cable and measuring head together form a measuring system. Measuring heads and electronics modules can be interchanged without limitations. No further adjustments are necessary.

Remark: Do not expose the electronics module and measuring head to heavy shocks or rough handling. Keep them in the original packing as long as possible. For further details refer to chapter 7.

3.1 Electronics module

Fig. 3.1. Electronics module of the HITACC current measuring system 3U version

The electronics is housed in a 3U high chassis for 19-inch rack mounting. It is advisable to support the chassis with L-brackets if mounted in a cabinet. The depth of the chassis is 400 mm, including the handles at the front and the connectors at the rear side. The top and bottom covers have vent slots for natural cooling. The HITACC Electronics Module is equipped with LED indicators for quick survey. They are locate in the front panel. In case the LED emits light a "true" situation is indicate. The front panel is also equipped with different potentiometers on which adjustment is prohibited.

See project specific drawing 'Dimensions of electronics module' for additional information.

Remark: A minimum space of 1U must be left between the modules. For example, at a continuous primary current of 4 kA, the dissipation inside the module will be approx. 60 W.

Place the HITACC-module in a dry and dust-proof cabinet with adequate ventilation. Air inlets and outlets must not be blocked by anything. Heat accumulation inside the electronics module will reduce the accuracy. Sources of heat below the electronics module should also be avoided for the same reason.

The relative humidity for the air surrounding the electronics module should be kept within the specified RH. Condensation moisture should be avoided as it can strongly degrade the specifications for accuracy.

WARNING! ***INCORRECT SUPPLY VOLTAGE WILL DAMAGE THE ELECTRONICS. CHECK, BEFORE APPLYING ANY VOLTAGE, IF THE INDICATED SUPPLY VOLTAGE ON THE ELECTRONICS MODULE MATCHES WITH THE LOCAL SUPPLY VOLTAGE.***

3.2 Measuring head

In most cases the head is delivered as a cast resin type. The resin type head has M12 nuts at P1 and P2 side for mounting purposes. Maximum torque for bolts with marking 8.8 is 85 Nm reduce this torque with 10 % if threads are oiled.

These nuts can also be used for hoisting by mounting two eyebolts at both sides. See drawing 'Dimensions of Measuring Head'. The measuring head can be used in any position. For the vertical position in most cases L-shaped feet are applied. There are several sizes of measuring heads. The casted heads have a metal terminal box for connecting the cable to the electronics module. Sometimes the head is bearing a bushing for insulating the primary voltage. See project specific drawings.

Measuring heads type H059S (single), H059D (double), H059T (triple) and H059Q (2x double) without a bushing can be mounted in any position with respect to seismic limitations (2 G). Measuring head H093 must be mounted upright.

Measuring heads with integrated bushings must be mounted upright as shown in figure 3.2.a.

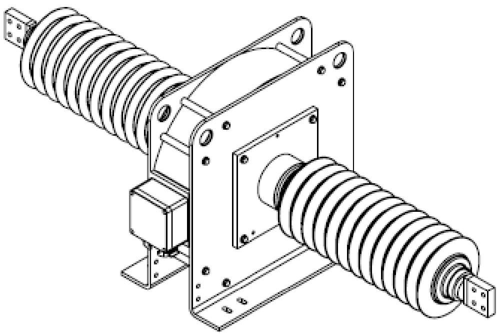


Fig. 3.2.a H059S with integrated bushing

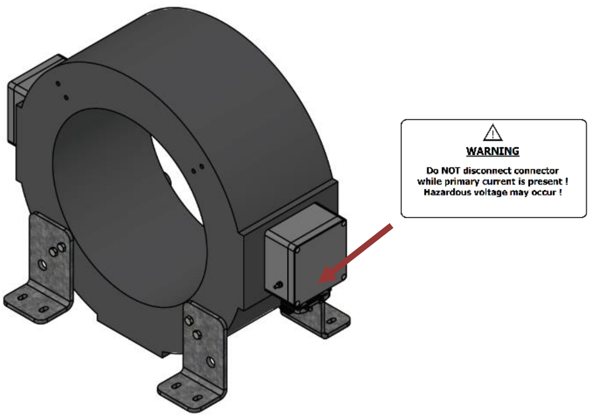


Fig. 3.2.b Size H059D with L-feet

⚠

WARNING

Do NOT disconnect connector
while primary current is present !
Hazardous voltage may occur !

Fig 3.2.c Warning label attached on cover of the connection box nearby the Harting connector.

3.3 Wall bushing

In some cases, a wall bushing is part of the delivery. The wall bushing is delivered separately and must be attached to the measuring head on site. Please refer to the project specific drawings and installation instructions of the wall bushing!

Fig. 3.3 Example of a wall bushing

3.4 VZF

Together with Pfiffner in Germany PM SMS has designed the VZF or free standing Zero-flux measuring head. The VZF is a fixed high voltage gas insulated measuring head build in a thick walled protection housing. The VZF footprint is significantly smaller compared to a wall bushing solution. Please refer to the service and maintenance manual MU2300 for more detailed information. In some cases up to four built-in measuring heads are possible. Please ask our sales department for more information.

Fig 3.4 Example of a VZF

4. Electronics module with industrial connectors

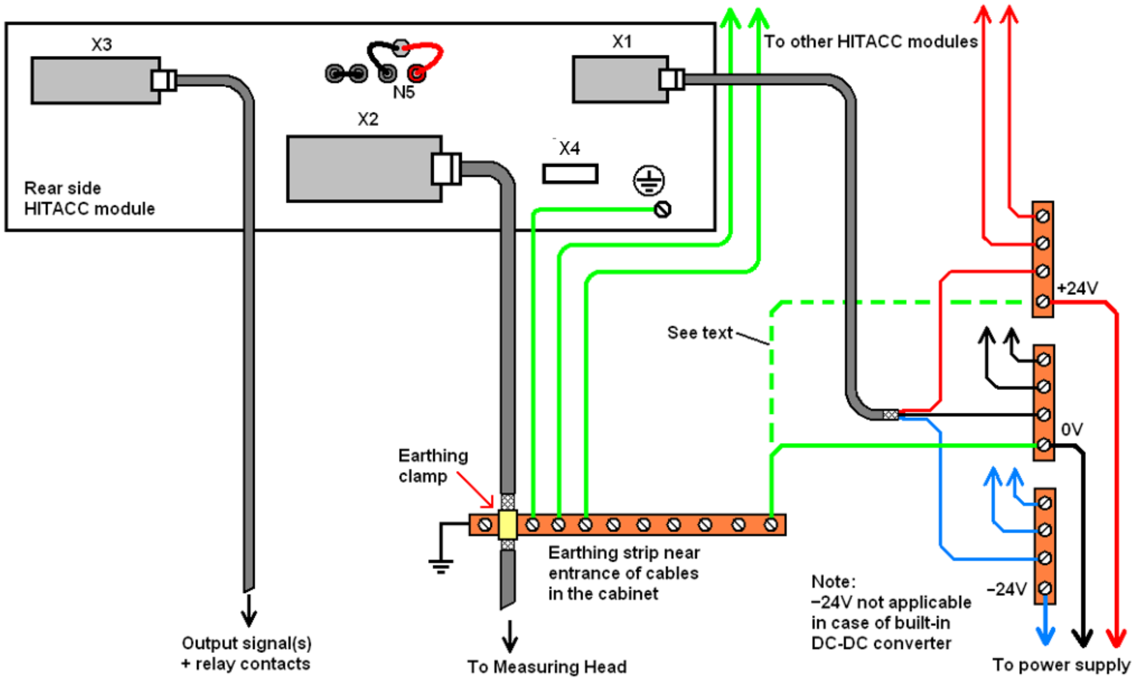


Fig. 4.1 Detailed connections for the HITACC module with connectors

4.1 Connections for the power supply

Wiring for HITACC modules that share the same supply source in or near a cabinet:

a) Modules with external +24 V / 0V / −24 V supply:

Distribution for a bipolar supply is supposed to be done on **three** copper strips inside the cabinet. From these strips, lead the +24 V and the –24 V via a two-pole automatic circuit breaker and the common (0 V) to the appropriate pins of connector X1. For the rating of the CB: see "Technical Specifications". If required for safety regulations, connect this commons distribution strip to earth inside the cabinet, rather than earthing in the battery room.

For connecting the supply lines a screened cable is advised. Connect the screen at the module side to the edge contact of connector X1 (= chassis). Connect the screen at the supply side to earth.

Note: For the bipolar supply option there is no galvanic insulation between the supply common and the electronic circuits connected with the measuring head and the analog output(s).

b) Modules with built-in DC-DC converter:

Distribution for a unipolar supply is assumed to be done on **two** copper strips inside the cabinet.
From here, lead the positive line via a single pole circuit breaker and the 0V-line to the appropriate pins of connector X1. For the rating of the CB: see "Technical Specifications". If required for safety regulations, connect the 0V distribution strip to earth inside the cabinet, rather than earthing in the battery room.

Note: In case the positive line of the supply system is earthed make the dotted connection (green).

For connecting the supply lines a screened cable is advised. Connect the screen at the module side to the edge contact of connector X1 (= chassis). Connect the screen at the supply side to earth.

4.2 Connections for the cable to the measuring head

The cable connecting the Electronics Module and the Measuring Head can be as long as 300 m. The cable consists of seven wire pairs. Each wire pair has an aluminum screen. The outer screen is a tinned copper braided screen. The outer sheath is made of black LSZH. Please refer to our document ZF02.377 for more detailed information about the cable. Please refer to our procedure ZF02.255 "cable mounting" to assemble this cable with its connectors.

The braided screen must be clamped onto the earthing strip at or near the place where the cable enters the cabinet. See drawing above. This braided screen must be continued to an earthing screw inside the hood of X2. Plugging-in X2 connects the braided screen with the chassis of the HITACC module.

Fig. 4.2 Gap in outer cable sheath for applying an earthing clamp

To be able to clamp the braided screen onto the earthing strip for effectively draining the screen currents to earth proceed as follows:
Carefully remove the black cable sheath over 5 cm with a knife. The braided screen prevents you for cutting through the underneath metalized foil screen. Do not cut or interrupt the braided screen.

4.3 Connections for the output signals and relay contacts

For carying one ore more output signals (see order specific drawings) a cable with twisted pairs plus an outer braided screen is advised. Connect the screen at the module side to the edge contact of connector X3 (= chassis). Connect the screen at the control room side to earth.

The status contacts also run through this cable. To minimize interference with the output signals use one twisted pair for each contact. To further minimize interference apply a cable type with twisted pairs, each having a metallized foil screen and one outer braided screen.

4.4 HITACC Diagnostics

At the rear side of the electronics module a 14-pole connector (X4) box is present to connect the separate Diagnostic Testbox. During installation the most important signals of the HITACC Current Measuring Systems can be measured. Please refer to sub clause 5.2 for more detailed information.

4.5 Earthing

The HITACC electronics module must be connected to earth. For proper earth connection a bus with M4 thread is present at the rear side of the electronics module. Wiring to earth must be done according to the schematic given in figure 4.1.

5. PRE-COMMISSIONING TESTS

WARNING: COLD REDUNDANT MEASURING HEADS WITHOUT INTEGRATED CTP5, WHICH ARE NOT CONNECTED TO AN ELECTRONICS MODULE, MUST HAVE ONE OF THE SECONDARY WINDINGS SHORT-CIRCUITED.

Errors or damage can happen when installing and connecting the cable between electronics module and measuring head. The purpose of the pre-commissioning tests is to ensure that no short circuiting is present between the individual circuits of the measuring head / neither connecting cable nor those interruptions exist within individual circuits. Abnormalities found during these test must be resolved before starting the functional test, which is part of the pre-commissioning tests.

Remark: For detailed information concerning external connections: see project specific drawings.

5.1 Electronics modules with industrial connectors

5.1.1 Insulation test of measuring head and cable

The tests shall be carried out using a DC-voltage of 500 V at a source resistance of 50 kΩ. The test voltage shall be applied between the appropriate points of the circuits under test. Properly discharge the involved circuits after each test.

Detach the 32-pole connector (X2) located at the electronics module. This will separate electronics from measuring head. The measuring head must be connected with the cable. The DC test voltage must be applied between the following groups of circuits:

a) All conductor pairs to all screens:
Connect all screens by chaining pins 5, 6, 14, and 29 the edge contact of the hood. Then interconnect all wire pairs. Apply the DC-test voltage between both groups. Alternatively each individual pair can be tested against all screens. Insulation resistance > 100 MΩ.

b) All pair-screens to the outer braided screen:
Connect all inner screens by chaining pins 5, 6, 14 and 29. Apply the DC test voltage between the grouped screens and the edge contact of the hood (outer braided screen). Insulation resistance > 100 MΩ.

c) Each winding to other windings:
There are 5 windings that should be insulated from each other: N_1, N_2, N_3, N_4 and N_5. Apply the DC test voltage between the interconnected terminals of N_1 and the interconnected terminals of N_2. Then N_1 against N_3, etcetera. Insulation resistance >100 MΩ.

5.1.2 Circuit resistance test

This test is recommended to determine whether the connections made between the measuring head and the electronics module are OK. Detach the 32-pole connector (X2) located at the electronics module Measure the resistance between the pins belonging to N_1, N_2, N_3, N_4 and N_5. The resistance value found for N_1 to N_5 is the loop resistance of one conductor pair (cable length, mm^2) increased with the winding resistance (R_{N1} = R_{N2} = R_{N3} approx. 2 Ω and R_{N4} , R_{N5}: 3…4 Ω). For N_4 and N_5 a number of conductor pairs is used. These pairs are paralleled inside the connecting box of the measuring head. The pairs also are paralleled inside the electronics module when connector X2 is put in place.

Please consult project specific drawings of PM for details.

5.2 Functional test with HITACC Diagnostics

Standard the 3U-high electronics module is delivered with test points available on the HITACC Diagnostics test box. Connect the HITACC Diagnostic test box with the ribbon cable to connector X4 located at the rear side of the electronics module. This ribbon cable is delivered together with the test box. This test makes it possible to check proper operation after the measuring head and power are connected correctly to the HITACC electronics module. This test does not include any additional output, either voltage or current output.

Remark: Do not mix up the reference numbers X1 to X4 on the rear side of the HITACC module with test points X1 to X4 on the test box!

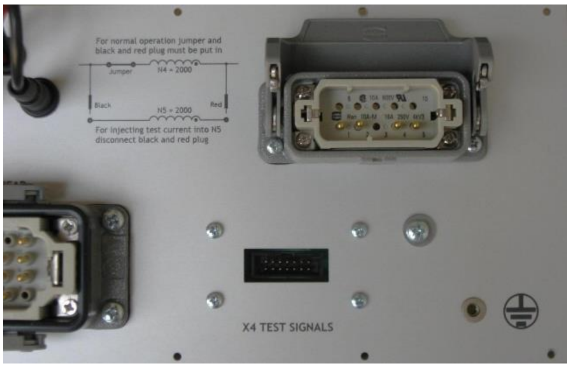


Fig. 5.2.a Test signal connector X4 located on the rear side of the HITACC electronics module

Fig. 5.2.b HITACC Diagnostics test box

Perform the subsequent steps:

a) Connect a supply source to X1 of the electronics module with the proper voltage and a power of at least 150 W.
   Please refer to the connection diagram for proper connection.
b) Disconnect the secondary windings N_4 and N_5.
   Remove jumper on the rear side of the module and pull out the red and black plugs.
c) Check the relay contacts: the contacts SUPPLY OK and OUTPUT VALID must be open.
d) Switch on the supply source and observe that the green LED "Power on" is lit, relay contact SUPPLY OK is *closed* and relay contact OUTPUT VALID is *open*.

5.2.1 Test points (4 mm sockets)

Remark: Do not apply any voltage to the test points located at the front panel. Test points are only for diagnostic purposes.

Note: All test points, except X4 and X11, have a series resistor of 10 kΩ.

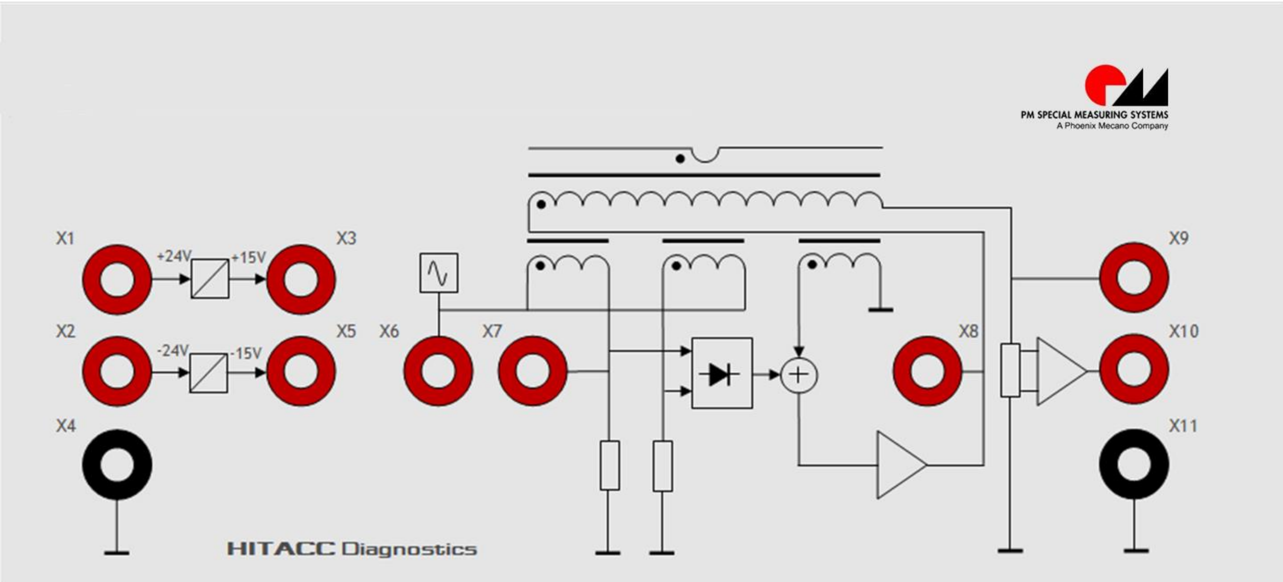


Fig. 5.2.c Location of test points on the HITACC Diagnostics test box

X1 = Positive internal supply voltage +24 V ±2.5 V

X2 = Negative internal supply voltage −24 V ±2.5 V

X3 = Stabilized positive supply voltage +15 V ±0.5 V

X4 = Common 0V

X5 = Stabilized negative supply voltage −15 V ±0.5 V

X6 = Excitation voltage (approx. 55 Hz, 9 V_{PEAK} ±2 V)

X7 = Magnetizing current of N1 (across approx. 40 Ω)

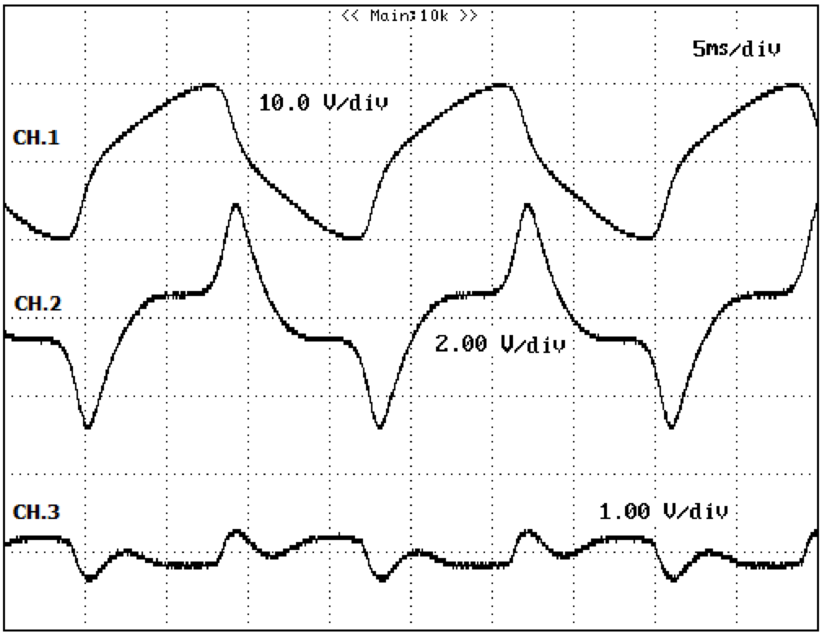
X8 = Output power amplifier ("induced voltage")

X9 = Signal across burden resistor

X10 = Voltage output signal

X11 = Common 0V

e) Measure the voltages at the various test points with respect to test point X4 or X11.
f) Measure the magnetizing current without any primary current. The peak value of the magnetizing current will automatically be adjusted to a level of 2.5 V_{PEAK} ±0.5 V and is independent from the size and the particular measuring head that is connected. See wave form below.
Note: with both N4 and N5 open the signal on X8 is maximum positive or negative.



Ch.1. Excitation voltage (Test point X6)

Ch.2. Magnetizing current (Test point X7)

Ch.3. Induced voltage (Test point X8)
See remark at j) below

Fig. 5.2.d typical waveforms (time base 5 ms/div)

g) Switch off the supply source.
h) Connect the secondary winding N_4 with the electronics.
   - Electronics module with terminals: close slides of terminals 9 and 12.
   - Electronics module with connectors: put the jumper back in place.
i) Switch on the supply source and observe that the green LED "Power on" is lit and relay contacts SUPPLY OK and OUTPUT VALID are closed.
j) Measure the 'induced voltage' in winding N_4 (test point X8).
   The DC-level must be near zero and the peak value of the AC-voltage must be < 5 V.

Remark: The signal on X8 can have <u>any</u> shape. However, the basic frequency will be the same as for the X6 and X7-signals. For optimal performance the 'induced voltage' is factory adjusted to a minimum. If for any reason the induced voltage must be re-adjusted please contact PM-SMS first. Only after consultation of PM-SMS adjustments may performed! On site this can be done with the BALANCE trim-pot accessible at the left-hand side at the front panel.

k) The output voltage (X10) of the precision amplifier must be zero when the primary current I_P or test current I_{N5} is zero. With current flowing in the primary circuit or into N_5, this output voltage must be according to the ratio as indicated on the rating plate, except in case of a current output. Then, the output is 2 V at 1pu value. See also chapter 'Accuracy check'.
l) Switch off the supply source and disconnect any circuit that might be connected with N_5.
m) Connect the secondary winding N_5 with the electronics (paralleling it with N_4).
   by putting the red and black plug back in place.

■ END OF TEST ■

6. ACCURACY CHECK

The accuracy check is subsequently described for systems with voltage output(s) and current output(s).
For the terminal numbers of the voltage output(s) or current output(s) please refer to the project drawings.

WARNING: FOR SAFETY PRECAUTIONS OF THE PERSONNEL THE CONNECTION OF COMPENSATING WINDING N4 MAY NOT BE OPENED IN ABSENCE OF PROTECTIVE DEVICE CTP5 IN THE MEASURING HEAD AND WINDING N5 IS SEPARATED. HIGH VOLTAGE DUE TO INDUCTIVE REACTION COULD BE POSSIBLE.

The accessible potentiometers at the front may only be adjusted in certain circumstances. Adjusting the Ratio potentiometer is prohibited. Calibration is void if this potentiometer is readjusted. Only after consultation of PM-SMS, adjustment of the potentiometers is allowed.

Fig. 6 Adjustments at the front of the electronics module HITACC

6.1 Voltage output

It is advised to check the accuracy of the measuring system (including spare electronics modules in stock) in a 5-year cycle using the test setup according to the figure below.
Any measuring head may be used for this purpose, including the one that normally is operated.

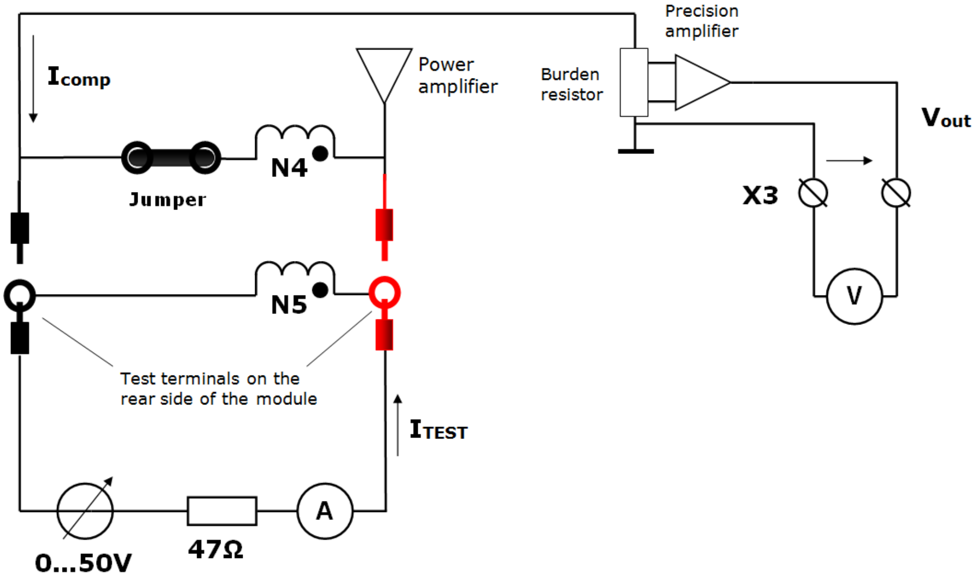


Fig. 6.1.a Test setup

IMPORTANT:
FOR PROPER EVALUATION OF THE ACCURACY NO PRIMARY CURRENT IS ALLOWED DURING THE TEST

The CONNECTING BRIDGE at the rear side of the Electronics Module may NOT be pulled out or interrupted.

Procedure:

a) Disconnect winding N_5 from N_4 on the electronics module side by pulling out the red and black plug.
b) Connect the indicated circuit to N5 and adjust a current I_{TEST} flowing into N_5 with a maximum that is approx. the rated primary current divided by the number of turns of N_5.
   For the number of turns of N_4 and N_5 see rating plate on the measuring head.
c) Measure the current in N_5 with an instrument that is accurate to within 0.05 %.
   The compensating current in N_4 will be equal to the test current due to the fact that the number of turns of N_4 and N_5 are equal (in most cases both windings have 2000 turns).
d) Measure the output voltage with a voltmeter (also accurate to within 0.05 %)

Note: Do not use test point number 10 on the front panel for the accuracy check.

The output voltage can be calculated with: $$V_{OUT} = \frac{I_{TEST}}{I_{p\,RATED}} \times V_{o\,RATED}$$

The measured output voltage should correspond with the calculated output voltage within the accuracy limits as originally agreed between the customer and PM Special Measuring Systems BV.

V_{OUT} = output voltage as calculated with the adjusted I_{TEST}

I_{TEST} = value of the current in winding N_5 as measured

$I_{p\,RATED}$ = rated primary current divided by the number of turns of N_5 (see rating plate MH)

$V_{o\,RATED}$ = rated output voltage at the rated primary current (see rating plate EM)

Notes:

- The series resistor for the 0-50 V source suppresses effects of "induced voltage" in N_5. The resistor must have an adequate power rating. A tolerance for this resistor of 5 % or 10 % is sufficient.
  'Induced voltage' originates due to small magnetic differences between the cores of N1 and N2. It is a wild-shaped AC voltage that is very characteristic for the measuring head observed. A series resistor reduces the 'induced current' that will flow as a result of the induced voltage into N5. Because of the fact that the HITACC is a current transformer this induced current is measured as well and therefore flowing through N4. At the output of the HITACC module this induced current will be presented also. The effect of induced voltage only arises in the above described test situation with a high number of turns for the test winding.
  Under normal measuring conditions (a one-turn primary bar), the small induced AC-voltage is not capable of producing an AC phantom current into the primary circuit.
- For rated primary currents up to 2 kA the 0-50 V source has to deliver 1 A. For rated currents up to 4kA the source must be able to deliver 2 A at 100 V (or 2 A at 50 V with a series resistor of 22 Ω).

e) Re-connect winding N_5 to N_4 on the electronics module side by putting in place the red and black plug.

■ END OF TEST ■

6.2 Current output

It is advised to check the accuracy of the measuring system (including spare electronics modules in stock) in a 5-year cycle using the test setup according to the figure below.
Any measuring head may be used for this purpose, including the one that normally is operated.

This description refers to the High Bandwidth output (HB).

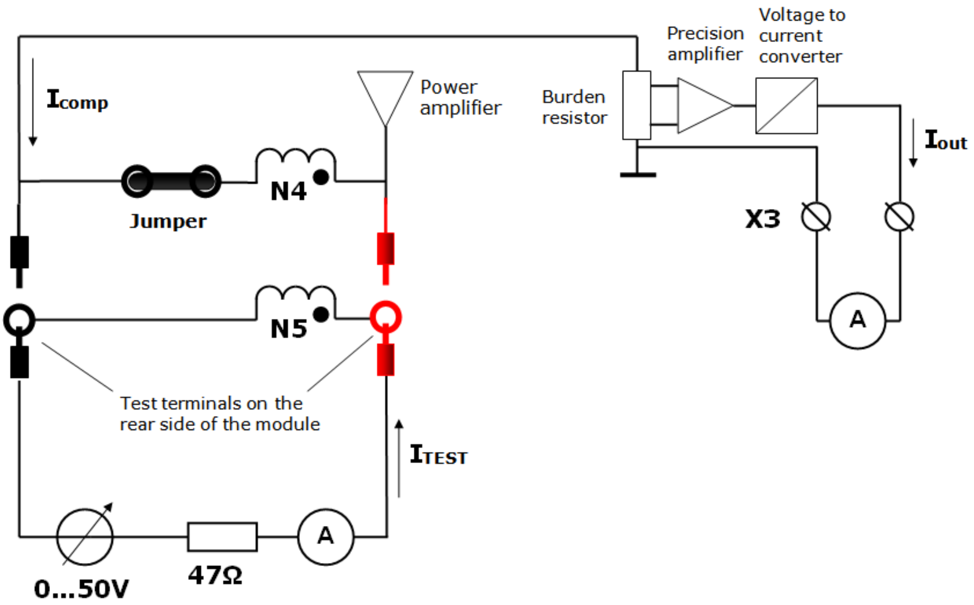


Fig. 6.2.a Test setup for electronics module with connectors

IMPORTANT:
FOR PROPER EVALUATION OF THE ACCURACY NO PRIMARY CURRENT IS ALLOWED DURING THE TEST

Procedure:

a) Disconnect winding N_5 from N_4 on the electronics module side by pulling out the red and black plug.

b) Connect the indicated circuit to N5 and adjust a current I_{TEST} flowing into N_5 with a maximum that is approx. the rated primary current divided by the number of turns of N_5.
For the number of turns of N_4 and N_5 see rating plate on the measuring head.

c) Measure the current in N_5 with an instrument that is accurate to within 0.05 %.
The compensating current in N_4 will be equal to the test current due to the fact that the number of turns of N_4 and N_5 are equal (in most cases both windings have 2000 turns).

d) Measure the output current at X3 of the electronics module with a current meter (also accurate to within 0.05 %)

The output current can be calculated with: $$I_{OUT} = \frac{I_{TEST}}{I_{p\,RATED}} \times I_{o\,RATED}$$

The measured output current should correspond with the calculated output current within the accuracy limits as originally agreed between the customer and PM.

I_{OUT} = output current as calculated with the adjusted I_{TEST}

I_{TEST} = value of the current in winding N_5 as measured

$I_{p\ RATED}$ = rated primary current divided by the number of turns of N_5 (see rating plate MH)

$I_{o\ RATED}$ = rated output current e.g. 100mA at the rated primary current (see rating plate EM)

Notes:

- The series resistor for the 0-50 V source suppresses effects of "induced voltage" in N_5. The resistor must have an adequate power rating. A tolerance for this resistor of 5 % or 10 % is sufficient.
  'Induced voltage' originates due to small magnetic differences between the cores of N1 and N2. It is a wild-shaped AC voltage that is very characteristic for the measuring head observed. A series resistor reduces the 'induced current' that will flow as a result of the induced voltage into N5. Because of the fact that the HITACC is a current transformer this induced current is measured as well and therefore flowing through N4. At the output of the HITACC module this induced current will be presented also. The effect of induced voltage only arises in the above described test situation with a high number of turns for the test winding.
  Under normal measuring conditions (a one-turn primary bar), the small induced AC-voltage is not capable of producing an AC phantom current into the primary circuit.
- For rated primary currents up to 2 kA the 0-50 V source has to deliver 1 A. For rated currents up to 4 kA the source must be able to deliver 2 A at 100 V (or 2 A at 50 V with a series resistor of 22 Ω).

e) Re-connect winding N_5 to N_4 on the electronics module side by putting in place the red and black plug.

■ END OF TEST ■

7. PACKING, TRANSPORT, STORAGE and MAINTENANCE

7.1 Packing

7.1.1 Normal packing

Tri-Wall pallet boxes will normally be used when transport takes place by truck or rail and rough handling is excluded. Closed wooden cases will be used when rough handling is to be expected. If necessary, shock absorbing material is provided. The electronics modules are packed in protective plastic bags.

7.1.2 Seaworthy packing

If transport takes place by boat or if the equipment has to be stored outdoors, closed wooden cases are used and the equipment is packed in sealed plastic bags. Additionally, shock absorbing material is provided.

7.1.3 Markings

The following symbols will be painted on boxes and cases:

Symbol "THIS SIDE UP"

Symbol "FRAGILE"

Symbol "LIFT HERE"

Symbol "CENTRE OF GRAVITY"

Fig. 7.1.3 Transport markings

7.2 Transport

7.2.1 In original packing

- Handle with care, although the goods withstand normal transport on rough roads.
- Do not drop or throw.

7.2.2 Without packing

- Handle with care.
- Suitable support must be provided when transported.
- Do not shake or vibrate.
- No stress is allowed on electrical leads.
- Goods must be protected against moisture and condensation.

7.3 Storage

7.3.1 In original packing

- Temperature limits:

  - Electronics module : 0°C < T ≤ +55°C

  - Measuring head : 0°C < T ≤ +70°C

- Relative humidity limits : 10% < RH ≤ 95%

- Goods must be kept dry.

- Fungus and vermin inadmissible.

- Maximum period of outdoor storage:

  - Normal packing: Not more than 7 days in respect to the specified conditions.

  - Seaworthy packing: 6 months, under the explicit condition that the original seaworthy packing is and stays undamaged and (is and stays) properly applied.

- Before commissioning, check according to the pre-commissioning testing instructions.

7.3.2 Without packing

- Goods can only be stored indoors.
- Temperature limits:

  - Electronics module: −20 °C < T ≤ +55 °C

  - Measuring head: −20 °C < T ≤ +70 °C

- Relative humidity limits: 10 % < RH ≤ 95 %
- Goods must be kept dry.
- Fungus and vermin inadmissible.
- Prevent for dust and dirt.
- Prevent for moisture and condense.
- Before commissioning, check according to the pre-commissioning testing instructions.

Remark:

In case the goods appear to be wet they must be dried in any case before installation and application.

In such a case it is recommended to use an oven at a temperature of maximum 50 °C for drying:

** Electronics module and measuring heads during 24 hours.*

7.4 Maintenance

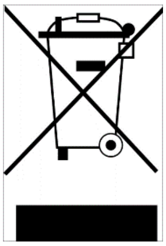
It is advised to check the accuracy of the measuring system (including spare electronics modules in stock) in a 5-year cycle using the test setup as described in sub clause 6.1 and 6.2. Once a year it is advised to clean the ventilation slots if necessary.

7.5 Warranty

Standard warranty period is one year from the date of delivery or such extended time as owner and supplier may agree in writing. Warranty is void if any seal is broken on the electronics module and or measuring head.

7.6 Waste Electrical and Electronic Equipment (WEEE)

Electronic equipment must be disposed according to the WEEE directive 2012/19/EU or if not applicable according to the local environmental protection requirements.



Appendix I Abbreviations

AC	Alternating Current
CTP	Current Transformer Protection
DC	Direct Current
EM	Electronics Module
EMC	Electro Magnetic Compatibility
EMI	Electro Magnetic Interference
HB	High Bandwidth
HV	High Voltage
LED	Light Emitting Diode
MH	Measuring Head
NB	Narrow Bandwidth
SF6	Sulphur Hexafluoride 6
I_N	Nominal current (indicated with 1 pu)
pu	per unit
I_P	Primary current