LAPCO HF6028

Transformer Differential Protection Device

Technical Manual, Volume 1

Pilot Installation of HF6028 relay on Sardar Jangal Substation

Pilot Installation of HF6028 relay on Balal Substation

Warning!

When electrical equipment is in operation dangerous voltage will be present in certain parts of the equipment. Failure to observe warning notices, incorrect use or improper use may endanger personnel and equipment and cause personal injury or physical damage. Before working in the terminal strip area, the Sharif LAPCO HF6028 must be isolated. Where stranded conductors are used, insulated crimped wire must be employed.

Any modifications to this LAPCO HF6028 must be in accordance with the manual. If any other modification is made without the express permission of Hamian Fan Company, it will invalidate the warranty, and may render the product unsafe.

Proper and safe operation of this LAPCO HF6028 depends on appropriate shipping and handling, proper storage, installation and commissioning, and on careful operation, maintenance and servicing.

Contents

INTRODUCTION

The Sharif LAPCO HF6028 differential protection device is intended for the fast and selective short-circuit protection of Two- windings transformers. The Sharif LAPCO HF6028 provides high-speed differential protection using a dual-slope characteristic and two high-set differential elements in combination with transformer inrush restraint, over-fluxing restraint. Amplitude and vector group matching is done just by entering the nominal values of transformer windings and associated current transformers.

In addition many supplementary protective functions are incorporated in the devices. These can be individually configured and cancelled. The relevant protection parameters can be stored in four independent parameter subsets in order to adapt the protection device to different operating and power system management conditions.

The number of external auxiliary devices required is largely minimized by the integration of binary signal inputs operating from versatile relay output contacts, by the direct connection option for current transformers, and by the comprehensive interlocking capabilities.

During operation, the user-friendly interface (SARA Software) makes it easy to set the device parameters and allows safe operation of the substation by preventing non-permissible switching operations.

The quality, reliability, and proven functions of LAPCO HF6028 give the user the means to adapt this relay to the protection and control capacity required in a specific application.

List of all protection functions in LAPCO HF6028 can be summarized as below:

- Differential Protection – 2 windings (87T)
- Inrush stabilization (functionality that is part of the Differential function group)
- Restricted Earth Fault Protection (87N)
- Definite-time Overcurrent Protection (50 P/Q/N)
- Inverse-time Overcurrent Protection (51 P/Q/N)
- Thermal Overload Protection (49)

In addition, LAPCO HF6028 has ability to record many faults, events and disturbances. All the needed information is stored during a fault. In particular the measured fault data, and the sampled fault waveforms are stored and can be read out when required.

HF6028 CAPABILITIES

- Vector group matching
- Amplitude matching
- Zero-sequence current filtering
- Nominal input current: 1 A and 5 A
- Four parameter subset selection
- 2X16 LCD display
- 8 two color LEDs (Relay status/programmable functions)
- 8 digital outputs
- 7 digital input
- Easy integration in substation Digital Control System or SCADA through Modbus.
- Compliance with international standard EN 60255-26 and EN 60255-27
- Native interactive Configuration Software
- Visual disturbance viewer to plot recorded COMTRADE files
- Disturbance Recording
    - Fault Recording: 25
    - Event Recording: 250
    - Disturbance Recording: 5 (Programmable Trigger for Start of Recording, Max Record Time: 3 seconds)

1 APPLICATION AND SCOPE

1.1 Overview – SHARIF LAPCO HF6028

The **LAPCO-HF 6028** differential protection device provides a fast and selective protection of sub-transmission transformers with two windings. Its' comprehensive integrated back-up protection functions such as time Restricted Earth Fault and overcurrent protections make additional protection devices obsolete.

Fig. 1.1 LAPCO HF6028 in 6 inch size case

The LAPCO HF6028 provides high-speed three phase differential protection using a dual slope characteristic and two high-set differential elements in combination with transformer inrush restraint, overfluxing restraint and through-stabilization. Amplitude and vector group matching is done just by entering the nominal values of the protected transformer windings and the associated current transformers.

In addition many supplementary protective functions are incorporated in the devices. These can be individually configured or cancelled. The relevant protection parameters can be stored in four independent parameter subsets in order to adapt the related protection device to different operating and power system management conditions.

The number of external auxiliary devices required to set up this protection in practice, is largely minimized by the integration of a set of binary signal inputs sampled from any auxiliary voltage, and versatile relay output contacts, and the direct connection option for current.

During its installation, the user-friendly interface makes it easy to set the device parameters and allows safe operation of the substation by preventing non-permissible operating conditions.

These features give a user the necessary means to adapt the LAPCO HF6028 to protect and control the transformer in a specific application. The powerful programmable logic provided in this protection device also makes it possible to accommodate some special applications.

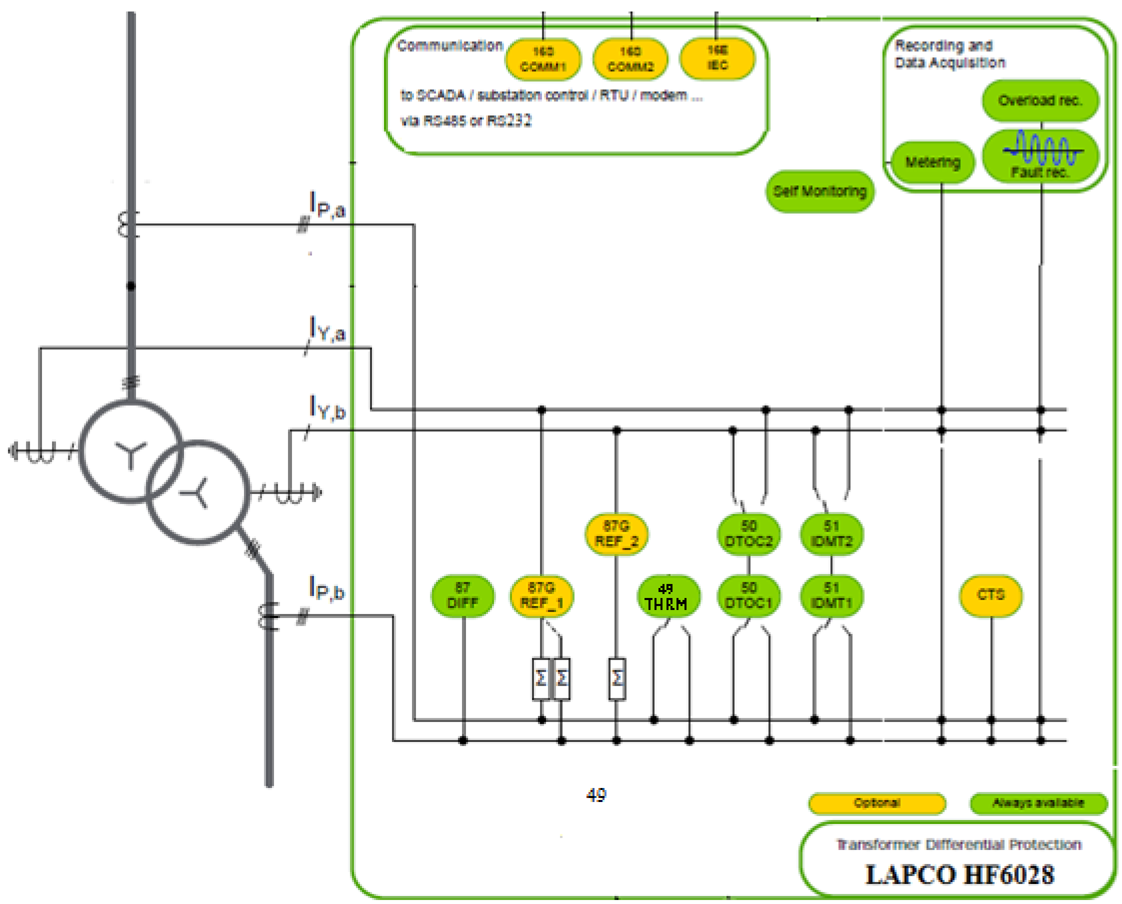


Fig. 1.2 Function diagram of LAPCO HF6028 relay

1.2 Including the Function Groups in the Configuration

All the available protection functions listed in the table1.1 are self-contained function groups and can be individually configured or de-configured according to the specific application requirements by using the SARA operating program.

This concept provides a large choice of functions and provides a wide range of applications of the protection device using this model version. On the other hand, simple and clear parameter settings can be applied. In this way the available protection and control functions can be included in or excluded from the configuration.

The table 1.1 list the available function groups that can be included in or excluded from the configuration of the LAPCO HF6028.

Table 1.1 Function Groups

Protection Functions				**LAPCO HF6028**
ANSI	**IEC61850**	**Function group**		
		Abbrev.	**Description**	
87T	PhsPDIF1	DIFF	Differential protection, phase selective	2 windings
	PHAR1		Inrush stabilization (functionality that is part of the DIFF function group)	Yes
87N		REF_x	Restricted earth-fault protection	2
50TD P/ Q/ N	DtpPhs- /DtpEft- /DtpNgsPTCOx	DTOCx	Definite-time overcurrent protection, 3 stages, phase-, negative-sequence-, residual/ starpoint -overcurrent	2
51 P/Q/ N	ItpPhs- /ItpEft- /ItpNgsPTCOx	IDMTx	Inverse-time overcurrent protection, one stage, phase-, negative-sequence-, residual/starpoint-overcurrent	2
49	ThmPTTR1	THRM1	Thermal overload protection 1	1
		CTS	Current transformer supervision	1

1.3 Inputs and Outputs

The nominal current values of the measuring inputs on the LAPCO HF6028 can be set with the function parameters. The nominal voltage range of the optical coupler inputs is 48 to 220 V DC and AC. As an option the binary signal input modules with a higher operating threshold are available.

The auxiliary voltage input for the power supply is also designed for an extended range. The nominal supply voltage ranges are 48 to 150 V DC and 48 to 130 V AC.

1.4 Control and Display

- Local control panel with an LC display containing 2 × 16 alphanumeric characters.
- 8 LED indicators, 4 of which allow freely configurable function assignment for the colors red and green. Furthermore there are various operating modes and flashing functions available.
- PC interface.
- Two communication interfaces for connection to a substation control system.

2 TECHNICAL DATA

2.1 Declaration of Conformity

The product designated "LAPCO HF6028 Transformer Differential Protection Device" has been designed and manufactured in conformance with the European standards EN 60255-26 and EN 60255-27 and with the "EMC Directive" and the "Low Voltage Directive" issued by the Council of the European Community.

2.2 General Data

2.2.1 General Device Data

Table 2.1 General Device Data

General Device Data	
Design	Flush mounted case suitable for cabinet and control panel
Installation Position	Vertical ±30°
Weight	Approx. 4.2 kg
Dimension	Case: Width : 147 mm, Height: 151 mm, Depth: 222 mm Front Panel : Width : 154 mm, Height: 177 mm, Depth: 246 mm
Terminals	PC Interface: a) EIA RS232 (DIN 41652) connector, type D-Sub, 9-pin b) wire leads: RS485
	current measuring inputs: Threaded terminal ends, pin-type cable lugs: M3, self-centering with cage clamp to protect conductor cross-sections 0.2 to 2.5 mm² (US: AWG25 to AWG14)

2.2.2 Dimensions diagram and Transformer Connections Terminals

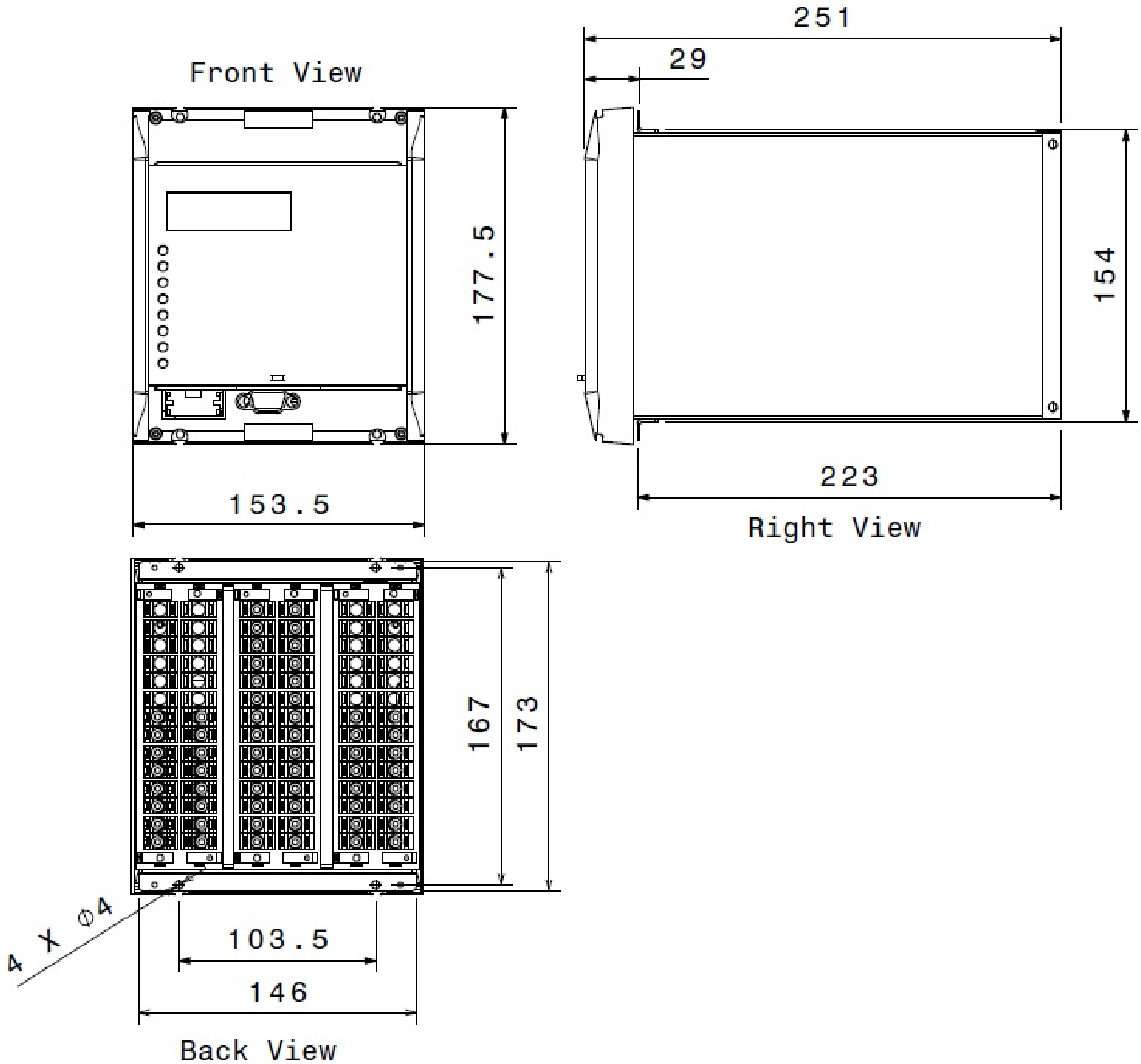
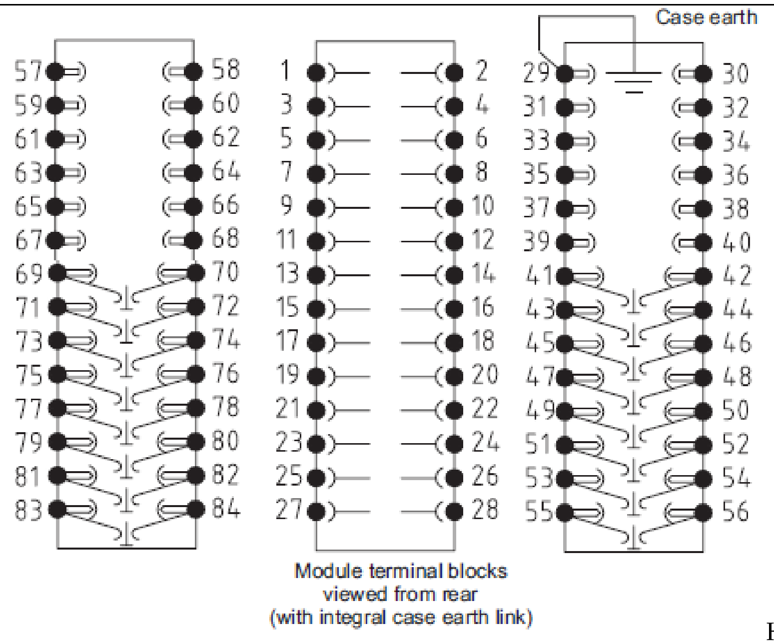


Fig. 2.1 Dimensions diagram of LAPCO HF6028 (different views)

2.2.3 Wiring Diagram



LV Side HV Side

Fig. 2.2 Wiring Diagram (Rear Terminals Description: LAPCO HF6028)

Input 7 +	57	58	Input 6 +
Input 7 –	59	60	Input 6 –
	61	62	
	63	64	
	65	66	
	67	68	
Current input IA (5A)	69	70	Current input IA (5A)
Current input IB (5A)	71	72	Current input IB (5A)
Current input IC(5A)	73	74	Current input IC(5A)
Current input Ie (5A)	75	76	Current input Ie (5A)
Current input IA (1A)	77	78	Current input IA (1A)
Current input IB (1A)	79	80	Current input IB (1A)
Current input IC(1A)	81	82	Current input IC(1A)
Current input Ie (1A)	83	84	Current input Ie (1A)

Output 5	1	2	Common output 1
Common output 5	3	4	Output 1 (NC)
Output 6	5	6	Output1 (NO)
Common output 6	7	8	Common output 2
Common output 7	9	10	Output 2 (NC)
Output 7	11	12	Output 2 (NO)
Common output 8	13	14	Output 3
Output 8	15	16	Common output 3
Input 3 +	17	18	Output 4
Input 3 –	19	20	Common output 4
Input 4 +	21	22	Input 1 +
Input 4 –	23	24	Input 1 –
Input 5 +	25	26	Input 2 +
Input 5 –	27	28	Input 2 –

Case earth connection	29	30	Terminal RS485
RS485 -	31	32	RS485+
Vaux +	33	34	Vaux –
Relay failed	35	36	Common "Watchdog"
Relay healthy	37	38	
	39	40	
Current input IA(5A)	41	42	Current input IA (5A)
Current input IB(5A)	43	44	Current input IB (5A)
Current input IC(5A)	45	46	Current input IC(5A)
Current input Ie (5A)	47	48	Current input Ie (5A)
Current input IA(1A)	49	50	Current input IA (1A)
Current input IB(1A)	51	52	Current input IB (1A)
Current input IC(1A)	53	54	Current input IC(1A)
Current input Ie (1A)	55	56	Current input Ie(1A)

2.2.4 Example connection of LAPCO HF6028 to a Transformer

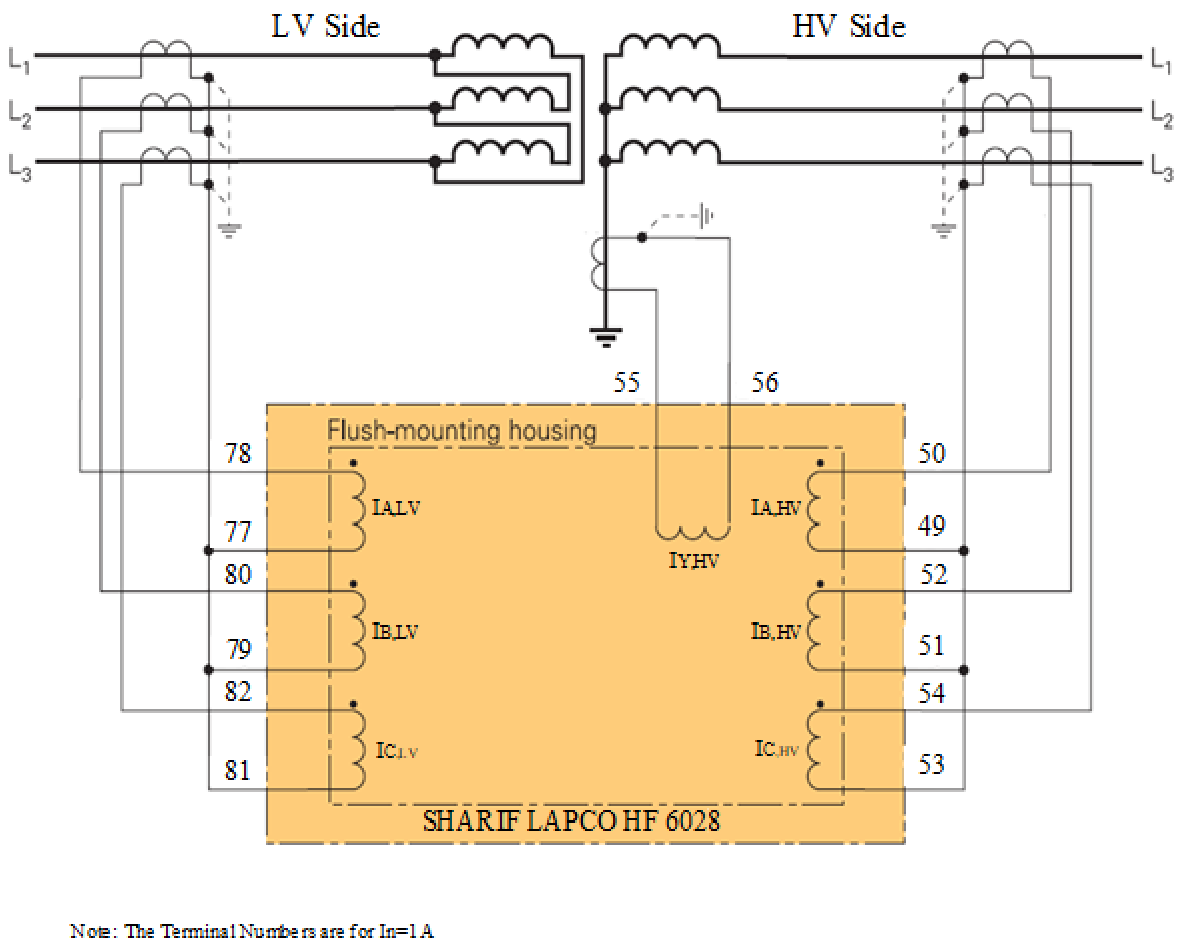


Fig. 2.3 HF6028 Terminals wiring for a 3 phase YND connected transformer

2.3 Inputs and Outputs

Table 2.2 HF6028 Inputs and Outputs parameters

Inputs		
Analog (current measuring)	Number	16
	Nominal current I_{nom}	1 and 5 A/AC (adjustable)
	Frequency	50 Hz
	Burden	<100 mVA at In = 1 A <600 mVA at In = 5 A
	Load rating	Continuous: 4 I_n For 1s: 100 I_n
	Nominal surge current	1250 A
Digital	Number	7
	Voltage Range	48 to 220 V DC/AC
Outputs		
Digital	Number	8
	Rated Voltage	250VAC
	Continuous current	8A
	Make current	Max. 30A and carry for 0.5s
	Operating Time	< 10 ms
	Reset Time	< 7 ms
Supply		
	Voltage Range	48 – 150 DC -10%+10% 48 – 130 AC -10%+10%
	Burden	(Normal/DC) 6W (Max./DC) 10W (Normal/AC) 10VA (Max./DC) 15VA
	Maximum Starting Time	15 Sec.

2.4 Interfaces

Table 2.3 HF6028 Interfaces

Local Control Panel	7 keys and 2×16 character liquid crystal display (LCD)
	8 2color LEDs indicators (3 permanently assigned, 5 freely configurable) Red Green
PC interface	RS232, RS485 with 119200 baud (nonadjustable) Communication Protocol based on: Modbus RTU

2.5 Setting – Typical Characteristics Data

Table 2.4 HF6028 Settings for Typical Characteristics Data

Main Function	▪ Minimum output pulse for trip command: 0.1 to 10 s (adjustable)
Differential Protection (87T)	▪ A dual slope percentage characteristic ▪ Two high-set differential relay ▪ Inrush stabilization ▪ Cross blocking timeout + Inrush blocking timeout ▪ Over-fluxing restraint
Restricted Earth-Fault Protection (87N)	▪ Two separated functions (REF1 and REF2) for primary and secondary windings ▪ Three operating modes: sum(IP), max(IP) and Zero(IP) ▪ High-set differential element
Definite-Time Overcurrent Protection (50 P/Q/N)	▪ Two separated functions (DTOC1 and DTOC2) for primary and secondary windings ▪ Three-stages, phase current protection (I>, I>>, I>>>) ▪ Three-stages, negative-sequence current protection (Ineg>, Ineg>>, Ineg>>>) ▪ Three-stages, residual current protection (IN>, IN>>, IN>>>) ▪ inrush blocking option
Inverse-time Overcurrent Protection (51 P/Q/N)	▪ Two separated functions (IDMT1 and IDMT2) for primary and secondary windings ▪ 4 tripping characteristics available for selection (IEC) ▪ One-stage, phase current protection ▪ One-stage, independent negative-sequence current protection ▪ One-stage, independent residual current protection ▪ inrush blocking option
Thermal Overload Protection	▪ Selectable input currents (primary or secondary windings) ▪ Two time constant (Heat and Cool) ▪ Both Trip and Alarm signals

2.6 Deviation

Reference Conditions: Sinusoidal signals at nominal frequency $f_{\mathbf{nom}}$, total harmonic distortion ≤ 2%, ambient temperature 20°C (68°F), and nominal auxiliary voltage $V_{\mathbf{A,nom}}$.

Deviation: Deviation relative to the setting under reference conditions.

2.6.1 Deviation Margins for the Operating Parameters

Table 2.5 Deviation Margins for the Operating parameters

Element	Deviation
Differential Protection	• Pick-up: formula ±5% • Drop-off: 95% of formula ±5% • Differential function operating time: with harmonic restraint: <28 ms including output relay: <36 ms • 2nd harmonic blocking Pick-up: Setting ±5% • 2nd harmonic blocking Drop-off: 95% of setting ±5% • 5th harmonic blocking Pick-up: Setting ±5% • 5th harmonic blocking Drop-off: 95% of setting ±5%
Restricted Earth-Fault Protection	• Pick-up: formula ±5% • Drop-off: 0.98 × formula ±5% • Operating time including output relay: for Sum(IP) function <26 ms for IP.max function <35 ms for Zero(IP) function <35 ms
Overcurrent-Definite Time Protection	• Pick-up: Setting ±2% • Drop-off: 95% of setting ±2% • Operating time including output relay: Setting ± 1% or 20 to 35 ms whichever is greater
Overcurrent-Inverse Time Protection	• Pick-up: 105% of Setting ±2% • Drop-off: 102% of setting ±2% • Operating time including output relay: According to IEC Characteristic Curves ± 5% or 20 to 40 ms whichever is greater (for $I < 40\ I_{Pick\text{-}up}$)
Thermal overload protection	• thermal overload characteristics: ± 5% + 10 to 20 ms • Operate value θ: formula ± 5%

2.6.2 Deviation Margins of Measured Data

Table 2.6 Deviation Margins of Measured Data

Element	Deviation	
Operational Data Measurement Unit	Currents (input data)	± 1%
	Currents (input data)	± 3%
Fault Data Acquisition Unit	Short-circuit current	± 3%

2.7 Resolution of the Fault Data Acquisition

Table 2.7 Resolution of the Fault Data Acquisition

Time Resolution	32 samples per period
Current Resolution	With Dynamic range of: 33. I_{nom}
	Amplitude resolution: ▪ at I_{nom} = 1 A: 1.0 mA_{rms} ▪ at I_{nom} = 5 A: 5.0 mA_{rms}

2.8 Recording Functions

Table 2.8 Recording Functions

Fault Recording	25 Separated Fault
Event recording	250 Separated Events
Disturbance recording	5 (Pre-fault time: 0.1 to 3 sec., max record time: 3 sec.)

2.9 Parameters Setting Ranges

Table 2.9 Parameters Setting Ranges

Element	Deviation
Differential Protection	• Idiff> 0.10 --- 2.5 (step : 0.01 Iref) • Idiff>> 2.5 --- 30 (step : 0.1 Iref) • Idiff>>> 2.5 --- 30 (step : 0.1 Iref) • m1 0.10 --- 1.50 (step : 0.01) • m2 0.10 --- 1.50 (step : 0.01) • IR,m2 1.5 --- 10 (step : 0.1) • RushI(2f0)/I(f0) 10 --- 50 (step : 1 %) • Rush Bl.Timeout 3 --- 1000 (step : 1 Cycle) • Cross Bl.Timeout 3 --- 1000 (step : 1 Cycle) • Ov. I(5f0)/I(f0) 10 --- 80 (step : 1 %) • Op.del.,trip sig 0.00 --- 100.00 (step : 0.01 s)

Restricted Earth-Fault Protection	• Idiff> 0.10 --- 1.00 (step : 0.01 Iref) • Idiff>>> 2.5 --- 30 (step : 0.1 Iref) • m1 0.00 --- 1.00 (step : 0.01) • m2 0.15 --- 1.50 (step : 0.01) • IR,m2 0.10 --- 2.5 (step : 0.01 Iref) • Zero Threshold 0.1 --- 2 (step : 0.01 Iref) • Zero Slope 0 --- 0.95 (step : 0.01 Iref) • Op.del.,trip sig 0 --- 100 (step : 0.01 s)
Element	**Deviation**
Overcurrent-Definite Time Protection	• I> 0.10 --- 30.00 (step : 0.01 Inom) • I>> 0.10 --- 30.00 (step : 0.01 Inom) • I>>> 0.10 --- 30.00 (step : 0.01 Inom) • t I> 0.00 --- 100.00 (step : 0.01 s) • t I>> 0.00 --- 100.00 (step : 0.01 s) • t I>>> 0.00 --- 100.00 (step : 0.01 s) • Ineg> 0.10 --- 8.00 (step : 0.01 Inom) • Ineg>> or Ineg>>> 0.10 --- 8.00 (step : 0.01 Inom) • t Ineg> 0.00 --- 100.00 (step : 0.01 s) • t Ineg> 0.00 --- 100.00 (step : 0.01 s) • t Ineg>> 0.00 --- 100.00 (step : 0.01 s) • t Ineg>>> 0.00 --- 100.00 (step : 0.01 s) • IN> 0.10 --- 8.00 (step : 0.01 Inom) • IN>> or IN>>> 0.10 --- 8.00 (step : 0.01 Inom) • tIN> 0.00 --- 100.00 (step : 0.01 s) • tIN>> 0.00 --- 100.00 (step : 0.01 s) • tIN>>> 0.00 --- 100.00 (step : 0.01 s) • tGS 0.00 --- 100.00 (step : 0.01 s)
Overcurrent-Inverse Time Protection	• Iref,P 0.10 --- 4.00 (step : 0.01 Inom) • Factor kt,p 0.05 --- 10.00 (step : 0.01) • Min. trip t.p 0.00 --- 100.00 (step : 0.01 s) • Hold time P 0.00 --- 600.00 (step : 0.01 s) • Iref,neg 0.01 --- 0.80 (step : 0.01 Inom) • Factor kt,neg 0.05 --- 10.00 (step : 0.01) • Min. trip t. neg 0.00 --- 100.00 (step : 0.01 s) • Hold time neg 0.00 --- 600.00 (step : 0.01 s) • Iref,N 0.01 --- 0.80 (step : 0.01 Inom) • Factor kt,N 0.05 --- 10.00 (step : 0.01) • Min. trip t. N 0.00 --- 100.00 (step : 0.01 s) • Hold time N 0.00 --- 600.00 (step : 0.01 s)

Thermal overload protection	• I Teta 0.10 --- 4.00 (step : 0.01 Inom) • Tim. Cons. Heat 1.1 --- 200.0 (step : 0.1 min) • Tim. Cons. Cool 1.1 --- 200.0 (step : 0.1 min) • K 1.00 --- 1.50 (step : 0.01) • Teta Trip 50 % --- 200 % (step : 1 %) • Teta Alarm 50 % --- 200 % (step : 1 %)

3 OPERATIONAL DATA EXCHANGE FACILITIES

3.1 Operator-Machine Communication

The following interfaces are available for the exchange of information between the user and the LAPCO HF6028:

- Integrated user interface (LOC: local control panel)
- PC interface
- Communication interface

All settings and signals as well as all measurements and control functions are arranged within a set of branches of the menu tree and follow a specific scheme. The main branches are:

3.1.1 "Parameters" Branch

All of relay settings are contained in this branch. This branch carries all of the settings, including the identification data of the LAPCO HF6028, the configuration parameters for adapting the LAPCO HF6028 interfaces to the system, and the function parameters for adapting the device functions to the process. All values in this group are stored in non-volatile memory, which means that the values will be preserved even if the power supply fails.

3.1.2 "Operation" Branch

This branch includes all information relevant for operation such as measured operating data and binary signal states. This information is updated periodically and consequently is not stored. In addition, various controls are provided in here, for example those for resetting counters, memories and displays.

3.1.3 "Events" Branch

The third branch is reserved for recording of the events. All information in this group is therefore stored. In particular, the start/end signals during a fault, the measured fault data, and the sampled fault waveforms are stored here and can be read out when required.

3.1.4 Display of Settings and Signals

Settings and signals are displayed either in plain text or as addresses, in accordance with the user's choice. All settings and signals of the LAPCO HF6028 are documented in a separate collection of documents, the so-called "HF6028 DataModelExplorer". The "Addresses" document (being part of the "HF6028 DataModelExplorer") is complete in the sense that it contains all settings, signals and measured variables that are relevant for the user of the LAPCO HF6028.

The configuration of the local control panel also permits the installation of Measured Value "Panels" on the LCD display. Different Panels are automatically displayed for specific system operating conditions. Priority increases from normal operation to operation under overload conditions and finally to operation following a short circuit in the system. Thus the LAPCO HF6028 provides the measured data relevant for the prevailing conditions.

3.2 Display Configuration

3.2.1 Operation Panel

The Operation Panel is displayed the measured values of three phase currents of each sides of the transformer and the neutral point if the neutral-point-to-ground connection is fitted with a current transformer. The user can see all these currents by pressing left or right key on the local control panel.

3.2.2 Fault Panel

The Fault Panel is displayed in place of another data panel when a fault happened. In this case, the ALARM warning displayed on the LCD. The user can press the Read (R) key on the local control panel to read the fault information, and press Clear (C) key to delete these information and fault memories, after the fault clearance. The Alarm message remains on display until the LED indicators or the fault memories are cleared.

3.3 Serial Interfaces

The LAPCO HF6028 has a PC interface as a standard component. A Communication module is provided with two communication channels. Communication between the HF6028 and the control station's computer is through this communication module.

3.3.1 PC Interface

Communication between the LAPCO HF6028 and a PC is through the PC interface. There is support software, called SARA available as an accessory for LAPCO HF6028 control. In order for data transfer between the LAPCO HF6028 and the PC to function, several settings must be made in the SARA.

3.3.2 Communication Interface 1

There is MODBUS interface protocol available at the communication interface 1. For data transfer to function properly, several settings must be applied to the SARA software. These settings can be seen in the figure 3.1.

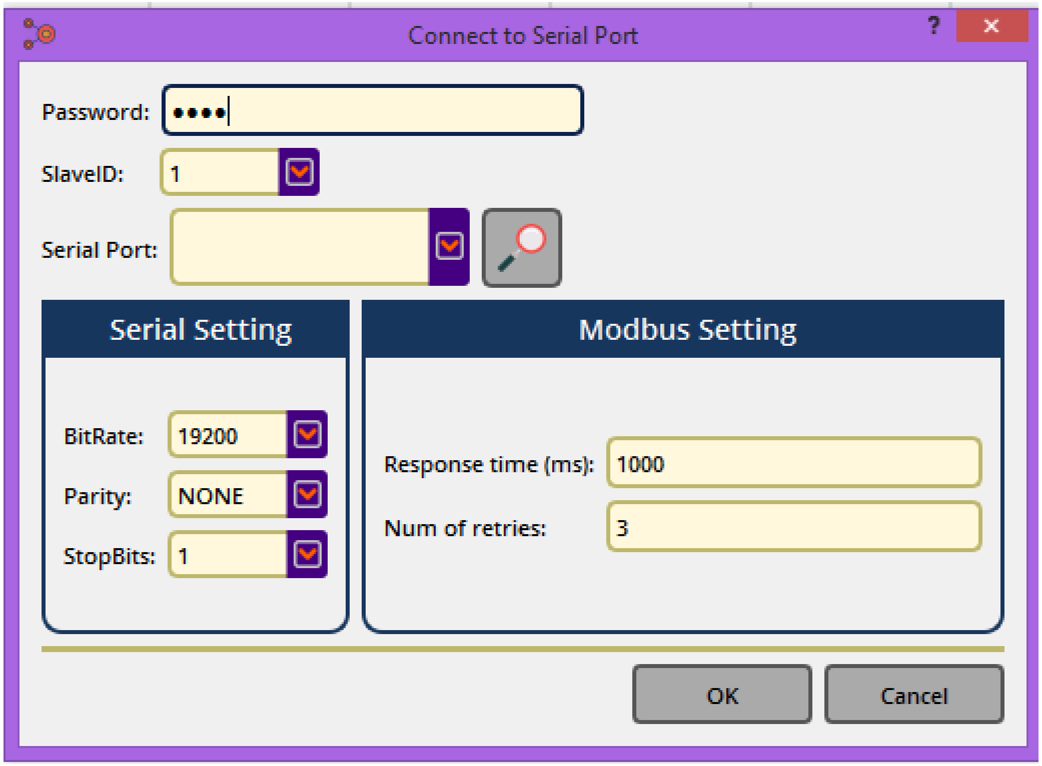


Fig 3.1 Serial port connection setting

3.4 Configuration and Operating Mode of the Binary Inputs (Function Group INP)

The LAPCO HF6028 has opto-coupler inputs for processing binary signals from the substation. The functions that will be activated in the LAPCO HF6028 by triggering these binary signal inputs are defined by the configuration of the binary signal inputs.

To ensure that during normal operation the LAPCO HF6028 will recognize an input signal, it must persist for at least 20 ms. Under a re-energization process this time period may have to be increased to 40 ms under unfavorable conditions.

3.4.1 Configuring the Binary Inputs

One function can be assigned to each binary signal input by configuration. The same function can be assigned to several signal inputs. Thus one function can be activated from several control points having different signal voltages. It should be noted that time-critical applications such as time synchronization commands should not be mapped to the binary signal inputs of the analog I/O module as these have an increased reaction time due to internal processing.

In this technical manual, it is assumed that the required functions (marked “EXT” in the address description) have been assigned to binary signal inputs by configuration.

3.4.2 Operating Mode of the Binary Inputs

The operating mode for each binary signal input can be defined. The user can specify whether the presence (*Active "high"* mode) or absence (*Active "low"* mode) of a voltage shall be interpreted as the logic ‘1’ signal. The display of the state of a binary signal input – "low" or "high" – is independent of the setting for the operating mode of the signal input.

3.5 Configuration, Operating Mode, and Blocking of the Output Relays (Function Group OUTPUTS)

The LAPCO HF6028 has output relays that supply output in form of binary signals. The binary signal assignment is freely configurable by the user.

3.5.1 Configuration of the Output Relays

One binary signal can be assigned to each output relay. The same binary signal can be assigned to several output relays by configuration.

3.5.2 Operating Mode of the Output Relays

The user can set an operating mode for each output relay that determines whether the output relay operates in latching mode or not. The first two output relays have normally open (NO) and normally closed (NC) contacts.

3.5.3 Blocking the Output Relays

The LAPCO HF6028 offers the option of blocking all output relays via a setting parameter or by way of an appropriately configured binary signal input. The output relays are likewise blocked if the device is disabled via appropriately configured binary inputs. In these cases the relays are treated according to their set operating mode, i.e. relays in a normally open mode (NO) are not triggered, whereas relays in a normally closed mode (NC) are triggered.

3.6 Configuration and Operating Mode of the LED Indicator (Function Group LED)

The HF6028 has 8 LED indicators for the indication of binary signals. Some of the LED indicators are permanently assigned to fixed functions. The other LED indicators are freely configurable. These freely configurable LEDs will emit either red or green or amber light (amber is made up of red and green light and may not be configured independently).

3.6.1 Configuring the LED Indicators

One binary signal can be assigned to each of the red and green LED color indications. The same binary signal can be assigned to several LED indicators (or colors), if required.

Table 3.1 Configuring the LED Indicators

LED indicator	Label	Configuration
LED 1 (red)	Trip	With the HF6028, this LED indicator is customarily configured with function MAIN: Gen. trip signal, but the configuration may be modified. LED 1 is permanently assigned to operate as latched mode
LED 2 (yellow)	Alarm	Not configurable. LED 2 is a blinking LED that signals the alarm.
LED 3 (red)	Warning	Not configurable. LED 3 signals a blocking or malfunction and indicates that the HF6028 is blocked or data is being transmitted form PC to the HF6028
LED 4 (Green)	Healthy	Not configurable. LED 4 indicates the operational readiness of the HF6028 (supply voltage is present).
LED 5 to LED 8	---------	For each of these LED indicators both colors (red & green) may be configured freely and independently.

3.6.2 Layout of the LED Indicators

The following figure illustrates the layout of LED indicators situated on the local control panel.

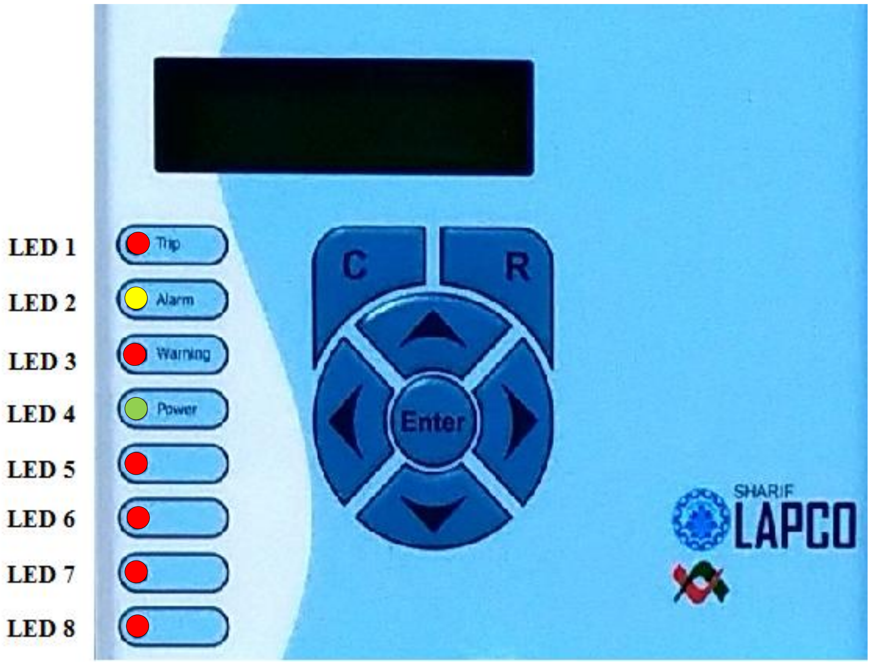


Fig. 3.2 Layout of the LED indicators.

3.6.3 Operating Mode of the LED Indicators

For each of the freely configurable LED indicators, the operating mode can be selected separately. This setting will determine whether the LED indicator will operate either in latched mode or unlatched mode. Latching is disabled manually via pressing the Clear key on local panel.

3.7 Main Functions of the HF6028 (Function Group MAIN)

3.7.1 Conditioning of the Measured Values

The secondary phase currents of the system transformers are fed to the HF6028. The measured values are – electrically isolated – converted to normalized electronics levels. The analog quantities are digitized and are thus available for further processing.

The HF6028 has the following measuring inputs:

- Current inputs (three phases) for processing of the measured values related to the 2 winding ends of the transformer.
- Two current inputs for the measurement of the residual currents (see Fig. 3.3, and Fig. 3.4) or, alternatively, for looping into ground connections of the phase current transformers.

3.7.2 Phase Reversal Function

The phase reversal function is intended to protect machines in pumped storage power stations that are operated either as motors or as generators, depending on the demand. In such applications it is common practice to swap two phases in order to facilitate the pumping operation. Because of this, the HF6028 phase reversal function can maintain correct operation of all protection functions even if phase reversal is carried out within the protected zone.

The processing is done right after A/D conversion, such that the link between physical transformer input and internal numerical signal will be swapped, depending on the setting. (The measured values stored in the respective measured value memories are swapped.) Thus all further processing of measured values and protection functions remains unchanged.

Phase reversal function can be set independently for each transformer side and in each parameter subset. These parameters are included in the function group of MAIN (in the *Parameters/Function setting/Protection Gx*) because phase reversal affects not only the differential protection function (DIFF), but also the negative sequence elements of Inverse and Definite Time Overcurrent protection functions (IDMTx, DTOCx) as well as Current Transformer Supervision (CTS) functions.

Table 3.2 Phase Reversal Function

Address				**Description**	**Range of Values**
PS1	**PS2**	**PS3**	**PS4**		
AC8	AC9	ACA	ACB	Phase reversal a PSx	● *No swap* (default) ● *A-B swapped* ● *B-C swapped* ● *C-A swapped*
ACC	ACD	ACE	ACF	Phase reversal b PSx	

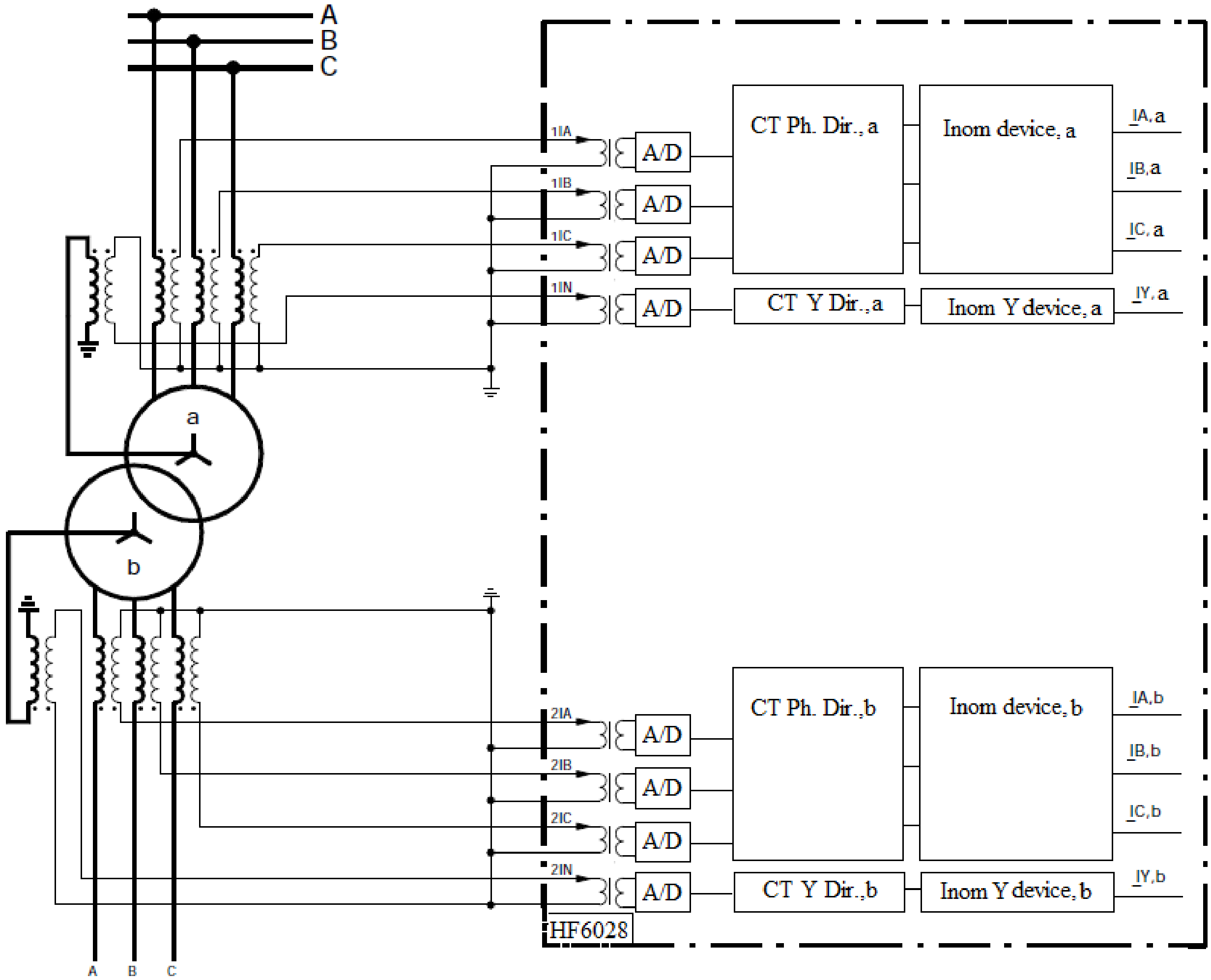


Fig. 3.3: Connection of the measured values to the HF6028, connection of the fourth current transformer set to the transformers of the neutral-point-to-ground connections

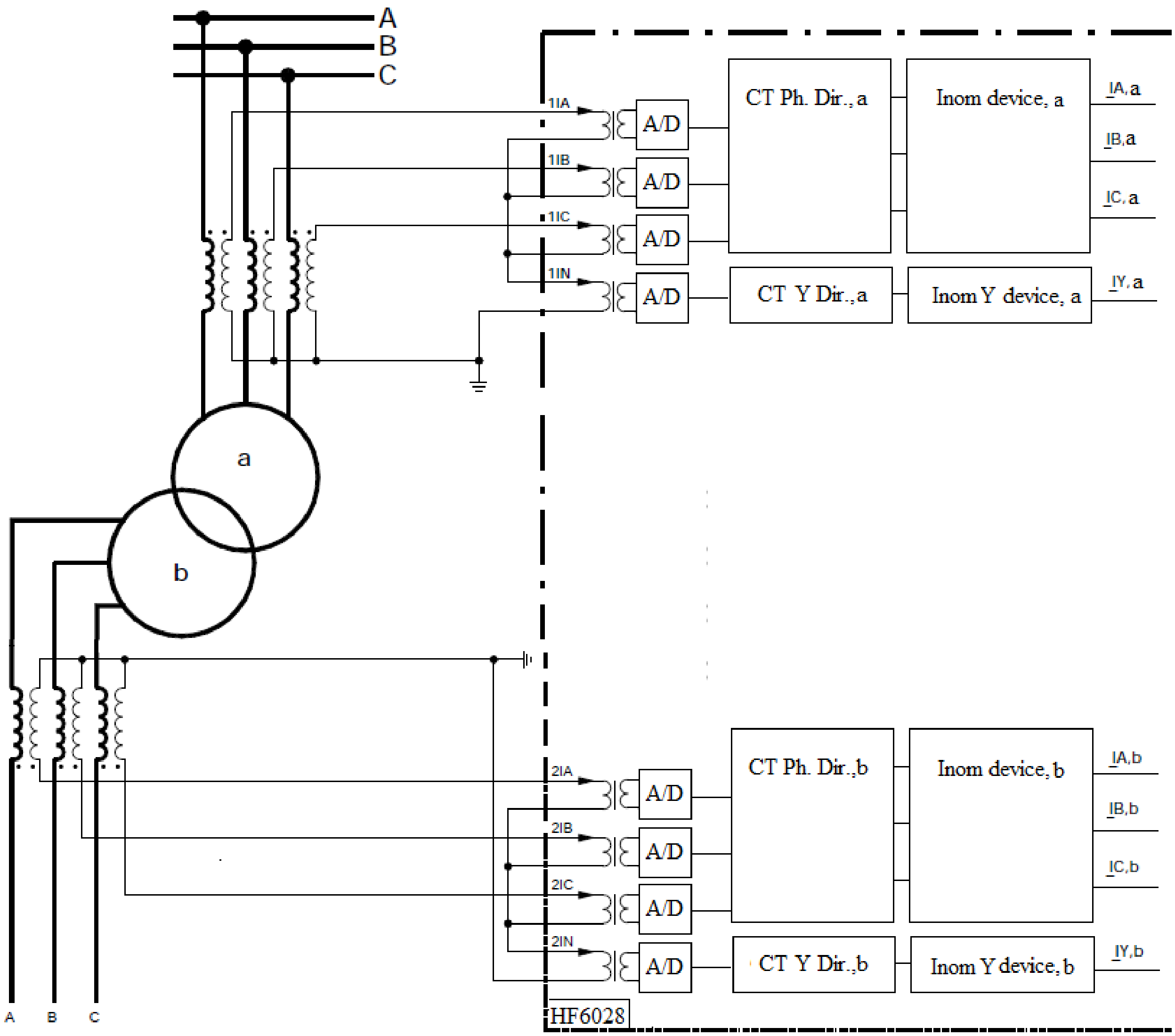


Fig. 3.4: Connection of the measured values to the HF6028, looping of the fourth current transformer set into the ground connections of the phase current transformers

3.7.3 Selection of the Residual Current to Be Monitored

For protection functions of the HF6028 monitoring the residual current, the user can select whether the device is to use the current derived from the three phase currents or the current measured by the fourth current transformer; see also Fig. 3.3.

Table 3.3 Selection of the Residual Current to Be Monitored

Parameter				**Address**
Default	**Min**	**Max**	**Unit**	
Evaluation IN,a				A90
Calculated				
Evaluation IN,b				A91
Calculated				
There are two choices to be Calculated or Measured. This setting specifies which current will be used by the HF6028 as the residual current: either the calculated residual current derived from the sum of the phase currents or the residual current measured at the fourth transformer.				

3.8 Configuring and Enabling the Device Functions

The HF6028 can be adapted to the requirements of a specific high-voltage system by configuring the available function range. By including the desired HF6028 functions in the configuration and disabling all other, the user creates an individually configured device appropriate to the specific application.

3.8.1 Disabling a Device Function

Before a HF6028 function can be disabled, the user should be noted that it is better that:

- None of the signals of the HF6028 function which are disabled be assigned to the binary inputs.
- None of the signals of the HF6028 function which are disabled be assigned to a binary output or an LED indicator.

3.8.2 Enabling or Disabling a Device Function

Besides disabling HF6028 functions from the configuration, it is also possible to disable protection via a function parameter or binary signal inputs. The setting can be done in the *Parameters/Config. Setting/INPUTS*.

3.9 Starting Signals and Tripping Logic

3.9.1 Starting Signals

The trip signals of differential protection and ground differential protection plus the general starting signals of the definite-time and inverse-time overcurrent protection functions are combined into one common general starting signal.

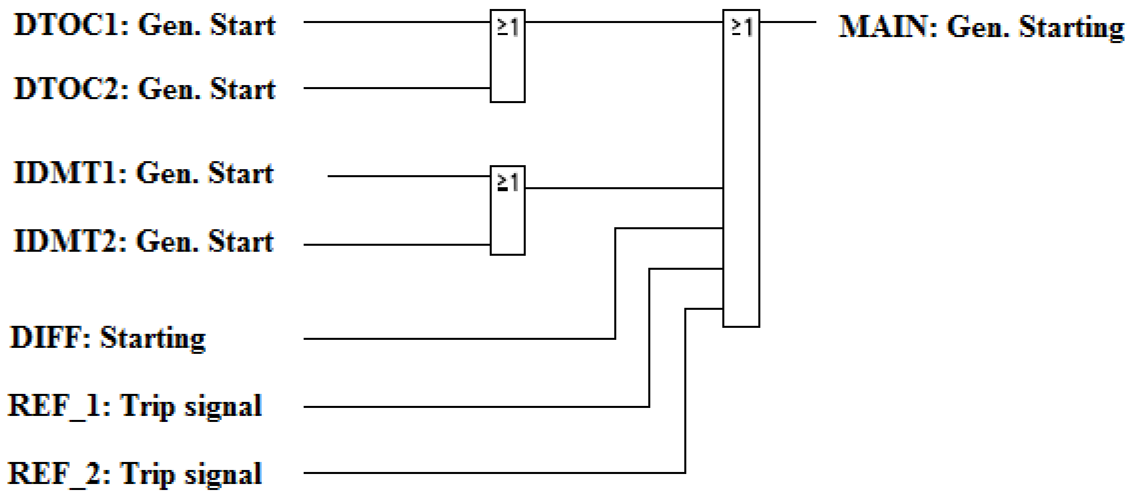


Fig. 3.5 general starting of the HF6028

3.9.2 Trip Command

The HF6028 has four trip commands. The functions to effect a trip can be selected by setting an 'm out of n' parameter independently for each of the four trip commands. The minimum trip command time may be set. The trip signals are present only as long as the conditions for the signal are met.

The following diagram shows the configuration of the trip commands, using the trip command 1 as an example. The parameters given apply to trip command 1. The corresponding parameters of the all of these four trip commands are given in SARA software (*Parameters/Function setting/Global/Main*).

3.9.3 Latching of the Trip Commands

For each of the four trip commands, the user can specify by way of the appropriate setting whether it will operate in latching mode. The trip command, set to latch mode, will remain active until reset by pressing Clear key.

3.9.4 Blocking of the Trip Commands

The trip commands can be blocked via parameters or an appropriately configured binary signal input. This blocking is then effective for all four trip commands. The setting can be done in the *Parameters/config. Setting/INPUTS* and select "Trip cmd Bl. X".

3.9.5 Resetting Actions

Stored data such as event logs, measured fault data etc, can be cleared in several ways. The following types of resetting actions are possible:

Resetting of LED indicators and measured event data displayed on the local control panel LCD by pressing the "Clear" key located on the local control panel. In this case only the displays on the local control panel LCD and LEDs are cleared but not the internal memories such as the fault memory. In case of showing "ALARM" message on the panel, user can press the READ (R) key and after watching the cause of trips, delete the causes by pressing “Clear” key and cleared the LEDs.

For clearing the saved disturbances, user should use the SARA software and press right click on the “Disturbance” part, and select “Erase Disturbance Records”.

- For clearing the saved events, user should use the SARA software and press right click on the “Event” part, and select “Erase Events Records”.

3.10 Test Mode

If tests are run on the HF6028, the user is advised to activate the test mode so that all incoming signals via the serial interfaces will be identified accordingly.

Table 3.4 Test Mode

Parameter **Default**	**Min**	**Max**	**Unit**	**Address**
Test Mode USER				30C
Disabled				
When the test mode user is activated, signals or measured data for PC and communication interfaces are labeled 'test mode'. In this situation all the output relays are blocked.				

3.11 Parameter Subset Selection (Function Group PSS)

With the HF6028, four independent parameter subsets may be pre-set. The user may switch between parameter subsets during operation without interrupting the protection function.

3.11.1 Selecting the Parameter Subset

The control path determining the active parameter subset can be selected by function setting or binary signal input. In other words, the parameter subset is selected either in accordance with the pre-set function setting PSS: Param.subs.sel. USER or in accordance with external signals.

3.11.2 Selecting the Parameter Subset via Function setting

User can change the active setting group in *Parameters/Function setting/Global/ PSS*.

Table 3.5 Parameter subset selection

Parameter **Default**	**Min**	**Max**	**Unit**			**Address**
		Param.Sub.Sel				33C
		Active Setting 1				

3.11.3 Selecting the Parameter Subset via Binary Inputs

The binary signal inputs can be used for parameter subset selection, when subset selection is handled via binary signal inputs, a maximum inherent delay of approximately 100 ms must be taken into account. User can assign PS1 Active X (or PS2 to PS4) to a binary input of HF6028 in *Parameters/Config. Setting/INPUTS*.

It should be noted that settings for which only one address is given in the following sections are equally effective for all four parameter subsets.

3.12 Operating Data Recording (Function Group OP_RC)

For the continuous recording of processes in system operation as well as of events, a non-volatile memory is provided (cyclic buffer). The “operationally relevant” signals, each fully tagged with date and time at signal start and signal end, are entered in chronological order. The signals relevant for operation include control actions such as function disabling and enabling and triggers for testing and resetting. The start and end of system events that represent a deviation from normal operation such as overloads, ground faults or short-circuits are also recorded. The operating data memory can be cleared/reset.

3.13 Fault Recording (Function Group FT_RC)

3.13.1 Start of Fault Recording

A fault exists and fault recording begins if the assigned trigger for fault recording is issued. The trigger option can be assigned in in the *Paramters/ Function Setting/ Global/ FT_RC*. Some of the most recommended options are:

- Main: Gen. starting
- Main Gen. trip
- Trip cmd 1….4
- …

Table 3.6 Fault Recording

Parameter Default	Min	Max	Unit	Address
Rec. Trigger Assign				355
Without function				
This setting defines the signals that will trigger fault recording.				

In addition fault recording may also be started externally through an appropriately configured binary signal input. To do so, user can assign Record Trigger X to a binary input of HF6028 in *Parameters/Config. Setting/INPUTS*.

3.13.2 Time Tagging

The date that is assigned to each fault by the internal clock is stored. A fault’s individual start or end signals are likewise time-tagged. The date and time assigned to a fault when the fault begins can be read out from the fault memory on the local control panel or through the PC and communication interfaces. The time information (relative to the onset of the fault) that is assigned to the signals can be retrieved from the fault memory or through the PC or communication interfaces.

3.13.3 Fault Recordings

Protection signals, including the signals during the settable pre-fault and post-fault times, are logged in chronological order with reference to the specific fault. A total of five faults, each involving some important fault signals, can be stored in the non-volatile fault memories. After eight faults have been recorded, the oldest fault recording will be overwritten, unless memories have been cleared in the interim.

In addition to the fault signals, the measured RMS fault data will also be entered in the fault memory. The fault recordings can be read from the local control panel or through the PC or communication interfaces.

3.13.4 Fault Waveforms Recording

The following analog signals are recorded:

- Phase currents of both ends of the transformer.
- Residual current measured by the HF6028 at the T 4 transformer.

The signals are recorded before, during and after a fault. The window length for oscillography recording before and after the fault can be set. A maximum time period of 3 s is available for recording of each of five faults. This maximum recording time can be set. If a fault, including the set pre-fault and post-fault times, lasts longer than the set maximum recording time, then recording will terminate when the set maximum recording time is reached.

The pre-fault time is exactly adhered to if it is shorter than the set maximum recording time. Otherwise the pre-fault time is set to the maximum recording time minus a sampling increment, and the post-fault time is set to zero. If the maximum recording time is exceeded, the values for the oldest fault are overwritten. If more than five faults have occurred since the last reset, then all data for the oldest fault are overwritten. The analog oscillography data of the fault record can only be read out through the PC or communication interfaces.

When the supply voltage is interrupted or after a warm restart, the values of all faults remain stored.

4 PROTECTION

4.1 Differential Protection

The HF6028 relay is designed for the protection of two-winding transformers. For transformer differential protection, amplitude matching is required. This is achieved simply by setting of the reference power -generally the nominal power of the transformer - and of the primary nominal voltages for all windings of the transformer.

Vector group matching is achieved by the straightforward input of the relevant vector group identification number. For special applications, zero-sequence current filtering may be deactivated. For conditions where it is possible to load the transformer with a voltage in excess of the nominal voltage, the overfluxing restraint prevents inappropriate tripping. It should be noted that **just for application as differential protection device for motors or generators**, the harmonic restraint (inrush compensation) can be deactivated.

All observations below are based on the assumption that the system current transformers are connected to the HF6028 in standard configuration (see Section 3.7.2). In particular, the application as transformer differential protection relay presupposes that winding 'a' corresponds to the high voltage side of the transformer. For a non-standard connection, the appropriate settings must be selected.

4.1.1 Enabling or Disabling Differential Protection

Differential protection can be enabled or disabled from the local control panel. Moreover, enabling can be done separately for each parameter subset.

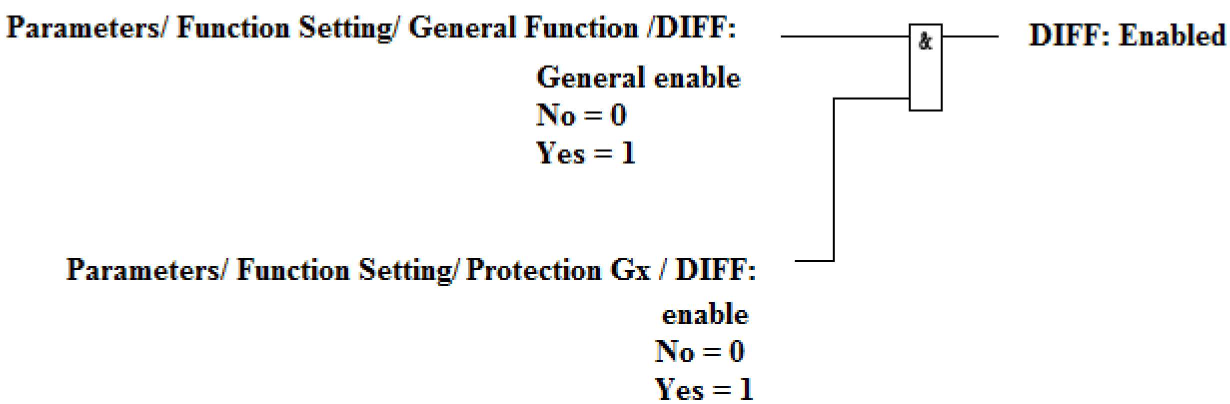


Fig. 4.1: Enabling or disabling differential protection

As shown in the Fig. 4.2, several processes must be performed on the relay input currents to be usable in the differential protection function.

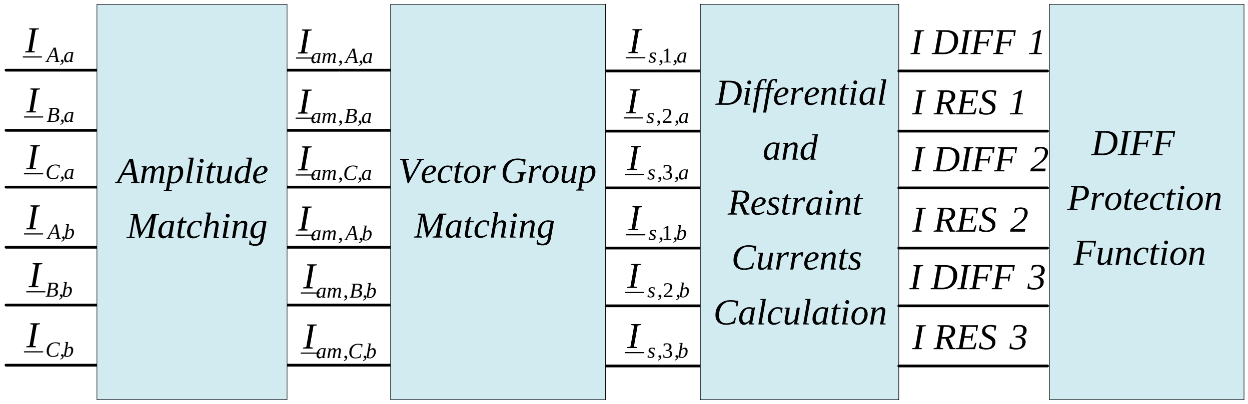


Fig. 4.2: Needed process for providing differential function inputs

4.1.2 Amplitude Matching

In order to set the amplitude matching for the protected object, a reference power - identical for all windings - needs to be defined. For two-winding arrangements, the nominal power will usually be the reference power. The individual reference currents for each winding of the protected object are then calculated by the HF6028 on the basis of the set reference power and the set primary nominal voltages of the transformer.

$$I_{ref,a} = \frac{S_{ref}}{\sqrt{3}.V_{nom,a}} \qquad I_{ref,\mathrm{b}} = \frac{S_{ref}}{\sqrt{3}.V_{nom,\mathrm{b}}}$$

S_{ref} : reference power

$I_{ref,a}$, $I_{ref,b}$: reference current of winding a or b, respectively.

$V_{nom,a}$, $V_{nom,b}$: nominal voltage of winding a or b, respectively.

The HF6028 calculates the matching factors on the basis of the reference currents and the set primary nominal currents of the system transformers.

$$k_{am,a} = \frac{I_{nom,a}}{I_{ref,a}} \qquad k_{am,b} = \frac{I_{nom,b}}{I_{ref,b}}$$

$k_{am,a}$, $k_{am,b}$: amplitude matching factor of end a or b, respectively

$I_{nom,a}$, $I_{nom,b}$: primary nominal currents of the system transformers Reference currents and matching factors are displayed at the HF6028.

The HF6028 checks if the reference currents and matching factors are within their permissible ranges. The matching factors must always be between 0.5 and 16: $0.5 \leq k_{am,a \text{ or } b} \leq 16$. If the HF6028 calculated reference currents or the matching factors not satisfying the above non-equality conditions then a warning will be issued and the HF6028 will be blocked automatically.

The measured values of the phase currents of the windings of the protected object are multiplied by the relevant matching factors and are then available for further processing. Consequently, all the threshold values and the measured values always refer back to the relevant reference currents rather than to the transformer nominal currents or the nominal currents of the device.

4.1.3 Vector Group Matching

Vector group matching means that the low voltage-side currents are rotated with respect to the high voltage-side currents according to the vector group of the transformer to be protected. Thereby, a phase coincidence with the high voltage side currents is restored. With the HF6028, this is achieved by calculating the relevant vector difference or where appropriate, by sign inversion check for the low voltage-side phase currents (end b). Care must be taken to avoid distortion of the amplitude matching by this operation. For all odd vector groups, this is achieved by means of the factor 1/√3. Using vector diagrams, it can be shown that the operations listed in the table 4.1 will lead to phase coincidence of the high and low voltage-side currents while maintaining the amplitude matching. In Fig. 4.3, such a vector diagram is depicted for a transformer having the vector group Yd5 as an example. By subtraction of each phase current from the cyclically leading phase current and subsequent multiplication by the factor 1/√3, the desired matching is achieved.

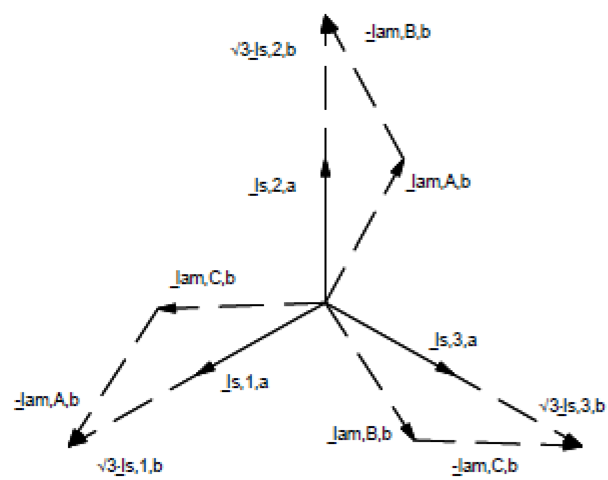


Fig. 4.3: Vector diagram for vector group matching with a transformer having the vector group Yd5

4.1.4 Zero-sequence Current Filtering

Table 4.1 shows that the zero-sequence current is subtracted from the phase currents of winding a and, for all even vector groups, from the phase currents of winding b. According to the theory of symmetric components, the zero-sequence current is calculated as follows:

$$\underline{I}_{am,0,z} = \frac{1}{3}[\underline{I}_{am,A,z} + \underline{I}_{am,B,z} + \underline{I}_{am,C,z}]$$

z: end a or b

$\underline{I}_{am}$: amplitude-matched current

Zero-sequence filtering may be disabled separately for each end.

In general this disabling of zero-sequence filtering is intended for even-numbered vector groups. Should the side considered here require the setting of an odd numbered vector group while at the same time no operational system star point grounding is provided within the protected area, then, in view of increased sensitivity with single-pole internal faults, it is recommended that the respective zero-sequence current is fed to the individual measuring systems again.

Zero-sequence filtering for the transformer ends a or b is enabled using the setting parameters:

- DIFF: 0-seq. filt.a en.PSx
- DIFF: 0-seq. filt.b en.PSx

The table 4.1 lists the required operations for all vector groups that may occur. The indices in the equations have the following meanings:

am: amplitude-matched

x: phase A, B or C

x+1: cyclically trailing phase

x-1: cyclically leading phase

Vector group matching is via a straight-forward input of the vector group identification number provided that the phase currents of the high and low voltage side are connected in standard configuration (see Fig. 3.4). For other configurations, special considerations apply.

A reverse phase rotation (A-C-B) needs to be taken into account by making the appropriate setting at the HF6028. The HF6028 will then automatically form the complementary value of the set vector group ID to the number 12 (vector group ID = 12 – set ID).

Table 4.1 Required operations for vector groups with or without zero-sequence current filtering

End	**ID of Vector Group**	**Setting: With zero-sequence filtering**	**Setting: Without zero-sequence filtering**
a		$\underline{I}_{am,x,a} - \underline{I}_{am,0,a}$	$\underline{I}_{am,x,a}$
b	0=12	$\underline{I}_{am,x,b} - \underline{I}_{am,0,b}$	$\underline{I}_{am,x,b}$
	1	$[\underline{I}_{am,x,b} - \underline{I}_{am,x+1,b}].\frac{1}{\sqrt{3}}$	$[\underline{I}_{am,x,b} - \underline{I}_{am,x+1,b}].\frac{1}{\sqrt{3}} + \underline{I}_{am,0,b}$
	2	$\underline{I}_{am,0,b} - \underline{I}_{am,x+1,b}$	$\underline{I}_{am,x+1,b}$
	3	$[\underline{I}_{am,x-1,b} - \underline{I}_{am,x+1,b}].\frac{1}{\sqrt{3}}$	$[\underline{I}_{am,x-1,b} - \underline{I}_{am,x+1,b}].\frac{1}{\sqrt{3}} + \underline{I}_{am,0,b}$
	4	$-\underline{I}_{am,x-1,b} - \underline{I}_{am,0,b}$	$\underline{I}_{am,x-1,b}$
	5	$[\underline{I}_{am,x-1,b} - \underline{I}_{am,x,b}].\frac{1}{\sqrt{3}}$	$[\underline{I}_{am,x-1,b} - \underline{I}_{am,x,b}].\frac{1}{\sqrt{3}} + \underline{I}_{am,0,b}$
	6	$\underline{I}_{am,0,b} - \underline{I}_{am,x,b}$	$\underline{I}_{am,x,b}$
	7	$[\underline{I}_{am,x+1,b} - \underline{I}_{am,x,b}].\frac{1}{\sqrt{3}}$	$[\underline{I}_{am,x+1,b} - \underline{I}_{am,x,b}].\frac{1}{\sqrt{3}} + \underline{I}_{am,0,b}$
	8	$\underline{I}_{am,x+1,b} - \underline{I}_{am,0,b}$	$\underline{I}_{am,x+1,b}$
	9	$[\underline{I}_{am,x+1,b} - \underline{I}_{am,x-1,b}].\frac{1}{\sqrt{3}}$	$[\underline{I}_{am,x+1,b} - \underline{I}_{am,x-1,b}].\frac{1}{\sqrt{3}} + \underline{I}_{am,0,b}$
	10	$\underline{I}_{am,0,b} - \underline{I}_{am,x-1,b}$	$\underline{I}_{am,x-1,b}$
	11	$[\underline{I}_{am,x,b} - \underline{I}_{am,x-1,b}].\frac{1}{\sqrt{3}}$	$[\underline{I}_{am,x,b} - \underline{I}_{am,x-1,b}].\frac{1}{\sqrt{3}} + \underline{I}_{am,0,b}$

4.1.5 Tripping Characteristics

The differential and restraining current values for each phase of measurement system are calculated from the current values after amplitude and vector group matching. The following equations are valid for uniformly defined current phasors relative to the protected equipment, e.g. all the current phasors of all windings point either towards the protected object or away from it.

Calculation of differential and restraining currents:

$$I_{d,y} = \left| \underline{I}_{s,y,a} + \underline{I}_{s,y,\mathrm{b}} \right|$$

$$I_{R,y} = \frac{1}{2} \left| \underline{I}_{s,y,a} - \underline{I}_{s,y,\mathrm{b}} \right|$$

The tripping characteristic of the HF6028 line differential protection device has two knee points. The first knee-point depends on the setting at DIFF: Idiff> PSx and is on the intersection with the tripping characteristic for single-side feed. In other words, the first Knee point is equal to IR/ Iref = 0.5. DIFF: Idiff> PSx.

The second knee of the tripping characteristic is defined by the setting of DIFF: IR,m2 PSx.

The characteristic equations for the three different ranges are given Fig. 4.4 shows the tripping characteristic.

This characteristics equation for the range $0 \le IR \le 0.5\ Idiff>$:

$$\frac{I_d}{I_{ref}} = \frac{I\,diff>}{I_{ref}}$$

and the characteristics equation for the range $0.5\ Idiff> \ < IR \ \le IR,m2$:

$$\frac{I_d}{I_{ref}} = m_1 . \frac{I_R}{I_{ref}} + \frac{I\,diff>}{I_{ref}} .(1 - 0.5.\mathrm{m}_1)$$

Characteristics equation for the range $IR,m2 < IR$:

$$\frac{I_d}{I_{ref}} = m_2 . \frac{I_R}{I_{ref}} + \frac{I\,diff>}{I_{ref}} .(1 - 0.5.\mathrm{m}_1) + \frac{I_{R,m2}}{I_{ref}} .(\mathrm{m}_1 - \mathrm{m}_2)$$

I_{ref}: reference current

m_1: gradient of the characteristic in range $0.5 Idiff> < IR \le IR,m2$

m_2: gradient of characteristic in range $IR,m2 < IR$

4.1.6 Rapid (high-set) Differential Protection

Above the adjustable threshold DIFF: Idiff>> PSx of the differential current, the HF6028 will trip without taking into account either the harmonic restraint or the overfluxing stabilization. If the differential current exceeds the adjustable threshold DIFF: Idiff>>> PSx, the restraining current and the saturation discriminator are no longer taken into account either, therefore the HF6028 will trip regardless of the restraining value and the saturation discriminator.

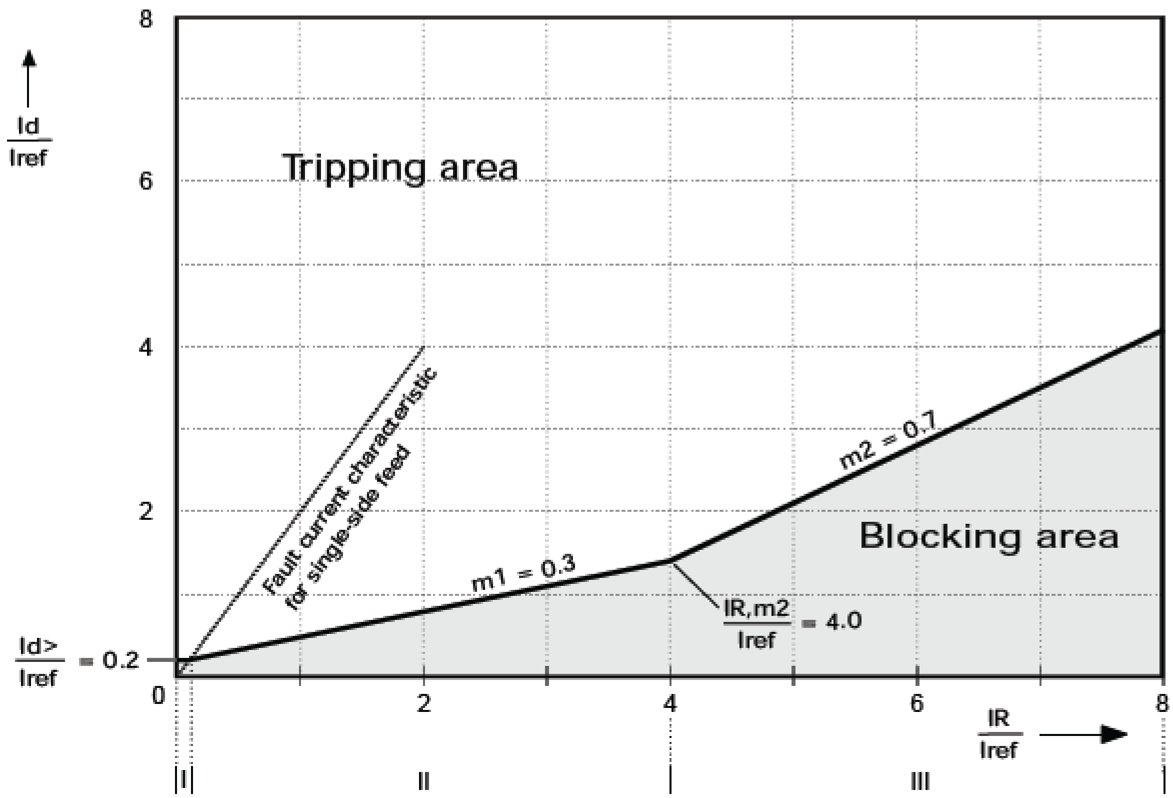


Fig. 4.4: Tripping characteristic of differential protection

4.1.7 Inrush Stabilization (Harmonic Restraint)

When an unloaded transformer is connected, the inrush current at unfavorable switching instants such as for voltage zero, may have values that exceed the transformer nominal current several times over. It takes some time for the current to assume its small stationary value. Since the high inrush current flows on the connected side only, the tripping characteristic of the HF6028 differential protection may give rise to a trip unless stabilizing action is taken. The fact that the inrush current has a high proportion of harmonics having twice the system frequency offers a possibility of stabilization against tripping by the inrush current.

The HF6028 filters the differential current. The fundamental wave $I\,(f\,0)$ and second harmonic components $I(2{\cdot}f\,0)$ of the differential current are determined. If the ratio $I(2{\cdot}f\,0)\,/\,I\,(f\,0)$ exceeds a specific adjustable value in at least one measuring system, tripping is blocked optionally in one of the following modes:

- Across all three measuring systems
- Selectively for one measuring system.

There will be no blocking if the differential current exceeds the set threshold DIFF: Idiff>> PSx.

The duration for which the inrush block function (Harmonic Restraint) is active can be limited by DIFF: Rush Bl.Timeout Setting. After this time, the inrush current detection unit will no longer block the differential protection operation.

Cross blocking: The inrush restraint can be extended by the so-called cross block function. This means that on harmonic content overshoot in only one phase all three phases of the differential stage DIFF: Idiff> stage are blocked. The duration for which the cross block function is active can be limited by DIFF: Cross Bl.Timeout Setting is in multiple of the AC-cycle. If set to blocked, the cross block function remains effective for as long as high-order harmonics are detected in any phase.

4.1.8 Current Waveform Analysis (CWA)

Besides detecting inrush currents using 2nd harmonic contents HF6028 offers an alternate method called Current Waveform Analysis (CWA). New transformer core materials, in order to reduce the noise level, and longer outage time of the transformer lead to a low content of 2nd harmonic current during energization (this means if a transformer is not energized for a long time, the first energization will not show enough 2nd harmonic content due to the magnetic flux). As a result, the lower content level does not reach the default threshold of 20% for 2nd harmonic restraint. The general approach to avoid a mal-trip of the differential protection in such scenarios is to decrease the threshold to 12% and to enable cross blocking for 2nd harmonic to 8 cycles. But one must also consider 2nd harmonics during internal faults. This leads to a certain risk for an under function of the differential protection if the 2nd harmonic settings are set too low with long cross-block durations.

If CWA function is enabled, this checks for any asymmetrical current waveforms and if any asymmetry exceeds a fixed level, then the differential protection tripping is blocked. The typical transformer energizing waveform is unsymmetrical in nature. Therefore, CWA provides a suitable alternative for stabilization of differential protection against transformer charging inrush and mitigates the risk of under function of differential protection due to low parameterization of 2nd harmonic restraint.

Typical for a transformer energizing process is the occurrence of flat areas in the current. If these flat areas occur in all 3 phases at the same time, this is a typical characteristic of this process. The CWA-method works as a supplement to the 2nd harmonic and covers cases that are not controlled through the 2nd harmonic. This function is based on analyzing the wave form. The physical behavior of an inrush current is asymmetric, additional pronounced flat areas exists. Based on the method of measurement, the blocking always affects all phases simultaneously.

4.1.9 Saturation Discriminator

Up to a certain limit, stability in the event of external faults is ensured by means of the bias. Due to the triple-slope tripping characteristic, the stabilization is particularly pronounced for high currents. However, as an additional safeguard for through-currents with transformer saturation, the HF6028 is provided with a saturation discriminator.

After each zero crossing of the restraining current, the saturation discriminator monitors the occurrence of the differential current over time. For internal faults, the differential current appears after a zero crossing together with the restraining current. In the case of passing currents with transformer saturation, however, a differential current will not appear until transformer saturation begins.

Accordingly, a locking signal is generated on the basis of level monitoring of the differential current as compared to the restraining current, and thus the desired through-stabilization is achieved. Locking is restricted to the measuring system where an external fault was detected.

There will be no blocking if the differential current exceeds the set threshold DIFF: Idiff>> PSx.

4.1.10 Overfluxing Stabilization

If the transformer is loaded with a voltage in excess of the nominal voltage, saturation effects occur. Without stabilization, these could lead to differential protection tripping. The fact that the current of the protected object under saturation conditions has a high proportion of harmonics having five times the system frequency serves as the basis of stabilization.

The HF6028 filters the differential current. The fundamental wave $I\ (f\,0)$ and fifth harmonic components $I\ (5.f\,0)$ of the differential current are determined. If the ratio $I\ (5.f\,0)\ /\ I\ (f\,0)$ exceeds the set value of DIFF: Ov. I(*5f0*)/I(*f0*) PSx in at least one measuring system, and if the differential current is smaller than 4·Iref, then tripping is blocked selectively for one measuring system.

There will be no blocking if the differential current exceeds the set threshold DIFF: Idiff>> PSx.

4.2 Ground Differential Protection (Function Groups REF_1 and REF_2)

The ground differential protection function (Br.: restricted earth fault protection) can be applied to transformer windings with grounded neutral point where the neutral-point-to-ground connection is fitted with a current transformer.

One ground differential protection function is available per transformer winding. The Hf6028 display shows the winding end associated with a particular ground differential protection function. Connection for and operation of the ground differential protection function will now be presented with end a as an example. Equivalent considerations apply to end b.

Ground differential protection may be applied to transformer ends with a grounded neutral-point, but in this case the neutral-point-to-ground connection must be fitted with a CT.

Ground differential protection is based on comparing the vector sum $\underline{I}N$ of the phase currents of the relevant transformer end to the neutral-point current $\underline{I}Y$. The Hf6028 calculates the vector sum of the phase currents. For the connection, see Section 3.7.2.

4.2.1 Enabling or Disabling Ground Differential Protection

Ground differential protection can be enabled or disabled from the local control panel; Moreover, enabling can be done separately for each parameter subset.

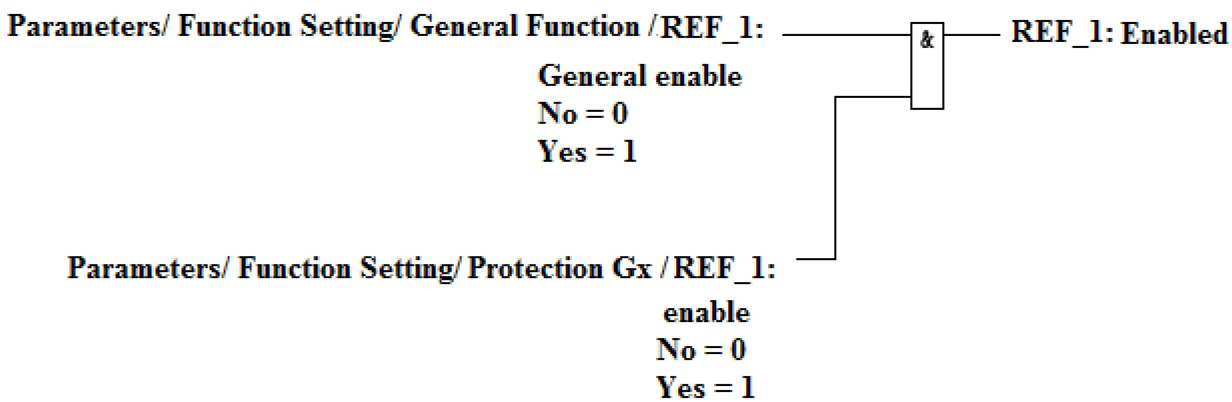


Fig. 4.5: Enabling, disabling and readiness of ground differential protection

4.2.2 Blocking ground differential protection

Blocking of the ground differential protection functions when the DIFF protection was triggered may be enabled or disabled using setting parameters. Furthermore, binary signal input functions (REF_1: Blocking X , for example) are available to allow for a more flexible application of the functions.

Since operational readiness is no longer solely dependent on the device setting, the readiness of ground differential protection is also indicated (by means of the REF_1: Ready state, for example).

3.22.3 Amplitude Matching

For amplitude matching, the nominal power of the transformer end should first be set as the reference power. The reference current is then calculated by the HF6028 on the basis of the set reference power and the set primary nominal voltage of the transformer end.

$$I_{ref,N,a} = \frac{S_{ref}}{\sqrt{3}.V_{nom,a}}$$

S_{ref} : reference power

$I_{ref,N,a}$: reference current of the ground differential protection function, end a

$V_{nom,a}$: nominal voltage of winding end a.

The HF6028 calculates the matching factors on the basis of the reference currents and the set primary nominal currents of the system transformers.

$$k_{am,N,a} = \frac{I_{nom,a}}{I_{ref,N,a}} \qquad k_{am,Y,a} = \frac{I_{nom,Y,a}}{I_{ref,N,a}}$$

with

$I_{nom,Y,a}$: primary nominal current of current transformer in the neutral-point-to-ground connection.

The HF6028 checks that the reference currents and matching factors are within their permissible ranges. The matching factors must always be between 0.5 and 16: $0.5 \leq k_{am,a \text{ or b}} \leq 16$. If the HF6028 calculated reference currents or matching factors not satisfying the above conditions then a warning will be issued and the HF6028 will be blocked automatically.

The measured values of the phase currents of the windings of the protected object are multiplied by the relevant matching factors and are then available for further processing. Consequently, all threshold values and measured values always refer back to the relevant reference currents rather than to the transformer nominal currents or the nominal currents of the device.

4.2.3 Operating Modes

The user can choose among three operating modes.

Table 4.2 Operating Modes

Address				Description	Range of Values
PS1	PS2	PS3	PS4		
4895	4995	4A95	4B95	REF_1: Operating mode PSx	*sum(IP)* (default) *IP,max, Zero(IP)*
48A9	49A9	4AA9	4BA9	REF_2: Operating mode PSx	

“*sum(IP)*” Operating Mode

From the amplitude-matched resultant currents $\underline{I}_{am,N,a}$ and $\underline{I}_{am,Y,a}$, the differential and restraining currents are calculated as follows:

$$I_{d,N,a} = \left| \underline{I}_{am,N,a} + \underline{I}_{am,Y,a} \right| \qquad\qquad I_{R,N,a} = \left| \underline{I}_{am,N,a} \right|$$

Again, the equation for the differential current applies under the condition of uniformly defined current arrows relative to the protected object. Both current arrows point either towards the protected object or away from it. Fig. 4.6 shows the tripping characteristic of the ground differential protection function. The characteristic equation is as follows:

$$\frac{I_{d,N,a}}{I_{ref}} = \frac{I_{diff>,N,a}}{I_{ref,N,a}} + 1.005 \frac{I_{R,N,a}}{I_{ref,N,a}}$$

with

$I_{diff>,N,a}$: setting at REF_1: Idiff> PSx.

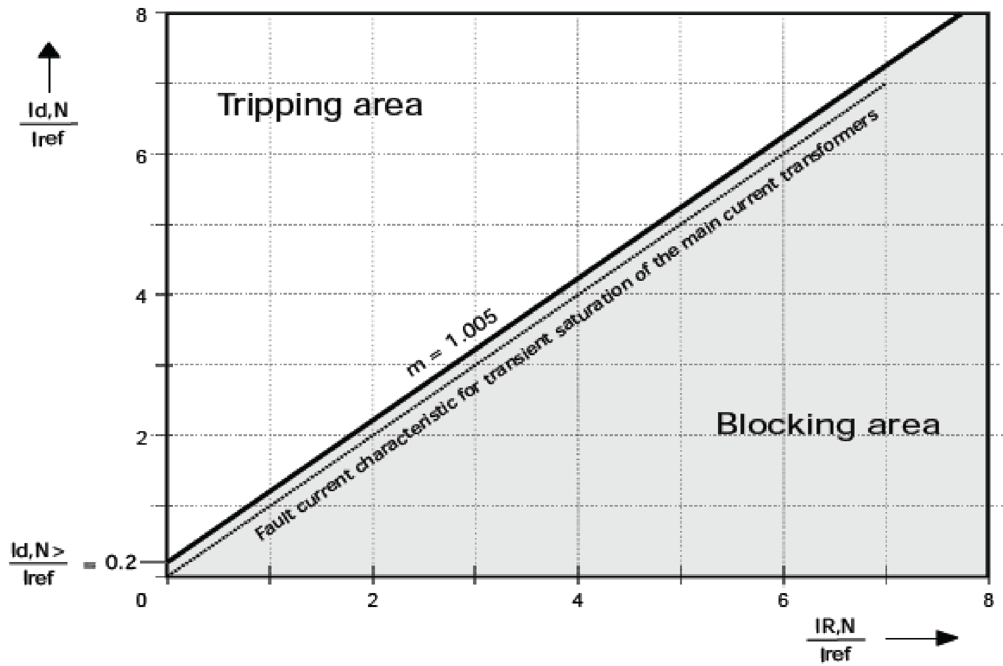


Fig. 4.6: Tripping characteristic of ground differential protection with the “sum(IP)” operating mode

“*IP,max*” Operating Mode

Using this operating mode differential current Id and restraining current IR are defined as follows:

$$I_d = \left| K_{am,P} \cdot \sum \left\{ \underline{I}_A + \underline{I}_B + \underline{I}_C \right\} + K_{am,Y} \cdot \underline{I}_Y \right|$$

$$I_R = \frac{1}{2} \cdot (K_{am,P} \cdot \max \left\{ \left|\underline{I}_A\right|, \left|\underline{I}_B\right|, \left|\underline{I}_C\right| \right\} + K_{am,Y} \cdot \left|\underline{I}_Y\right|)$$

When compared to the "*sum(IP)*" operating mode, a double slope tripping characteristic can be used here because of the definition of the restraining current. In particular, this tripping characteristic permits a tripping test under load current by shorting a phase current (to simulate residual current) without the need of star point current IY.

Besides the REF: Idiff> parameter, already available to set the basic pick-up sensitivity, the following parameters are also provided with the "*IP,max*" operating mode to set the tripping characteristic; in this case IR,m2 is equivalent to I_{ref}.

Table 4.3 REF Setting Range

Address				**Description**	**Range of Values***
PS1	**PS2**	**PS3**	**PS4**		
48A2	49A2	4AA2	4BA2	REF_1: m1 PSx	0.00 … {0.20} … 1.00
48A3	49A3	4AA3	4BA3	REF_1: m2 PSx	0.15 … {1.50}
48A4	49A4	4AA4	4BA4	REF_1: IR,m2 PSx	0.10 … {1.00} … 1.50
48AC	49AC	4AAC	4BAC	REF_2: m1 PSx	0.00 … {0.20} … 1.00
48A5	49A5	4AA5	4BA5	REF_2: m2 PSx	0.15 … {1.50}
48A6	49A6	4AA6	4BA6	REF_2: IR,m2 PSx	0.10 … {1.00} … 1.50

* Default setting in curly braces {}

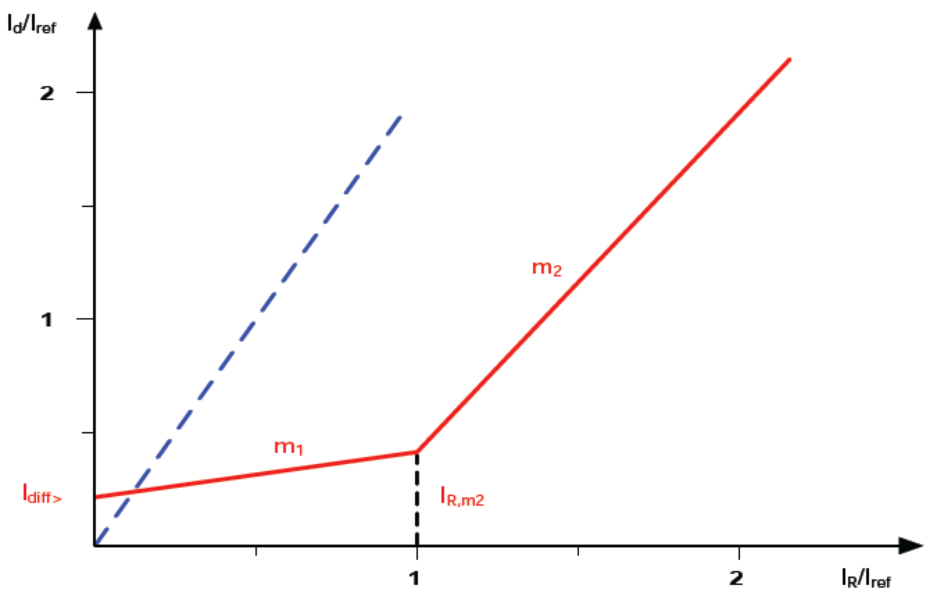


Fig. 4.7: Tripping characteristic of the ground differential protection with the "IP,max" operating mode

“*Zero(IP)*” Operating Mode

The Restricted ground-fault protection function (ANSI 87N, REF):

- Detects ground faults in transformers, shunt reactors, neutral reactors or rotating machinery in which the neutral point is grounded.
- Has high sensitivity to ground faults near the neutral point.
- Is supplemental main protection to longitudinal differential protection.
- Protects grounding transformers in the protection range. It is required that a current transformer be used in the case of neutral point feed, that is, between neutral point and grounding conductor. The neutral point transformer and the phase current transformer define the protection range.

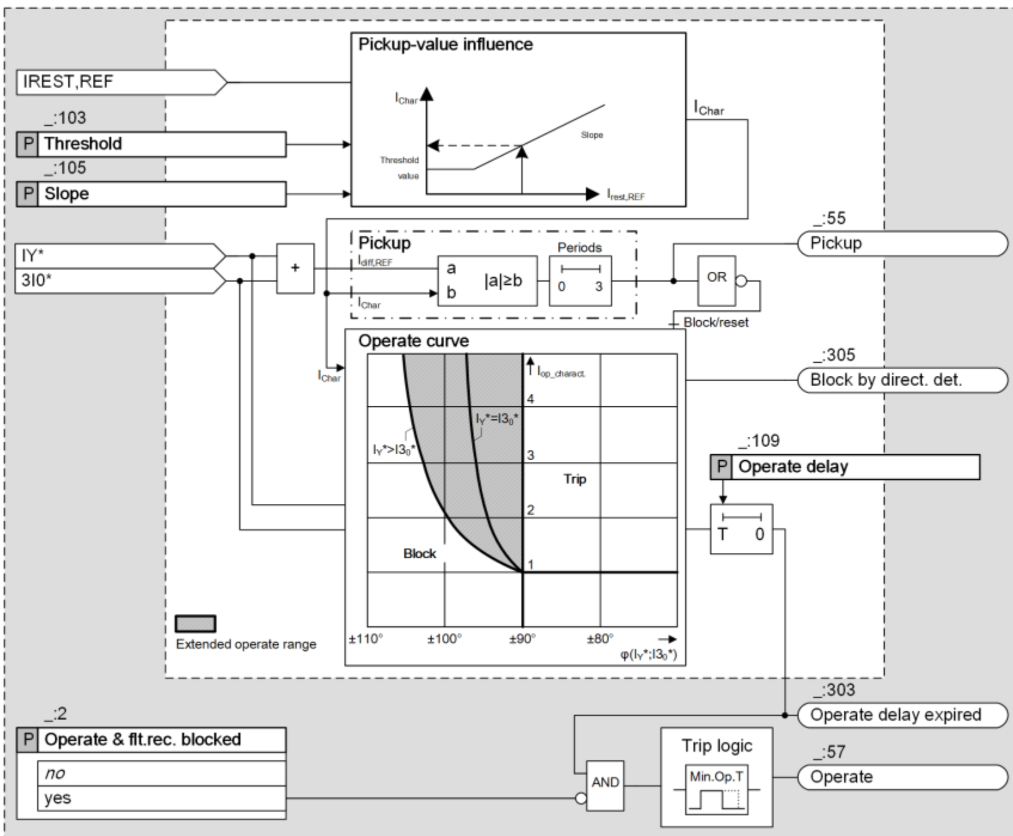


Fig. 4.8: Logic Diagram of the Restricted Ground-Fault Protection Function

In accordance with the logic diagram Figure 4.8, the protection function operates in 3 step:

- Effect on the pickup value: Increasing the set pickup threshold using the restraint current. This prevents mal-operation in case of high current external ground faults.
- Pickup: If the calculated current I_d exceeds the adapted pickup threshold, pickup starts.
- Operate curve based on phase-angle difference: To differentiate between internal and external faults, the angle difference between the neutral-point current (IY) and the

calculated vector summation of three phase currents (IN) is taken into consideration in the operate curve.

The restraint current ($I_{R,N,a}$) is calculated from the measured currents. The reference arrows are defined as positive when pointing to the protected object (see Figure 4.8). Consider that the neutral-point current (IY) detected using the 1-phase measuring point is displayed as positive if the current flows from the protected object to ground.

$$I_{d,N,a} = \left| \underline{I}_{am,N,a} + \underline{I}_{am,Y,a} \right|$$

$$I_R = K_{am,P} \cdot \left(\left| \underline{I}_A \right| + \left| \underline{I}_B \right| + \left| \underline{I}_C \right| \right) + K_{am,Y} \cdot \left| \underline{I}_Y \right|$$

Using the calculated restraint current, a current I_{Char} which represents the pickup value for the tripping is determined from the characteristic curve (Figure 6-96) and settings of REF: Zero Threshold and REF: Zero Slope. In this way, the protection function is stabilized in the event of external, multiphase ground faults, for example, a 2-pole ground fault. This means that the protection function becomes less sensitive.

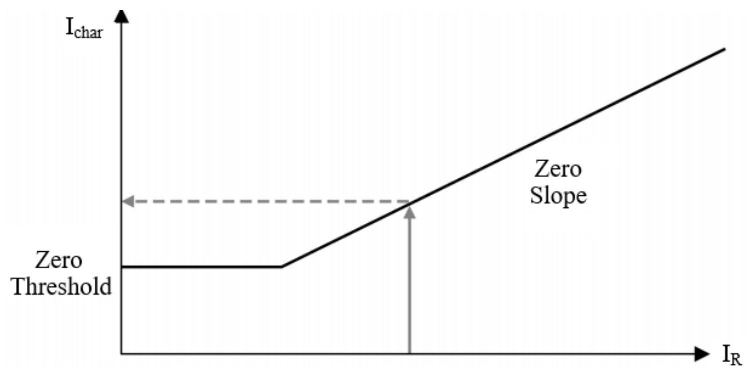


Fig. 4.9: Stabilized Characteristic Curve

Pickup: If the $I_{Diff,REF}$ calculated differential current exceeds the calculated current, pickup occurs and the internal processing is enabled. The pickup is indicated.

Also The current $I_{Angle,REF}$ for the Angle Decision is determined from the following subtraction and summation:

$$I_{Angle,REF} = \left| \underline{I}_{am,Y,a} - \underline{I}_{am,N,a} \right| - \left| \underline{I}_{am,Y,a} + \underline{I}_{am,N,a} \right|$$

With an external fault, the current $I_{Angle,REF}$ is always > 0.

For tripping to occur, the neutral-point current I_Y must reach the value $I_{REF,Trip}$. The $I_{REF,Trip}$ is determined from the following relationship:

$$I_{REF,Trip} = I_{Char} + 4.05657 \times I_{Angle,REF}$$

If $I_{Angle,REF}$ is positive and I_Y is greater than $I_{REF,Trip}$, or if $I_{Angle,REF}$ is negative and current I_Y is greater than calculated I_{char}, an internal fault is detected.

4.3 Definite-Time Overcurrent Protection (Function Groups DTOC1 and DTOC2)

In the HF6028, a three-stage definite-time overcurrent protection function (DTOC protection) is available. The measured values to be monitored by the respective DTOC functions are selected using a setting parameter. Phase current values as well as negative-sequence and residual current measured values are monitored.

The function group DTOC1 will serve as an example to illustrate the operation of the DTOC protection functions. The same will apply to function group DTOC2.

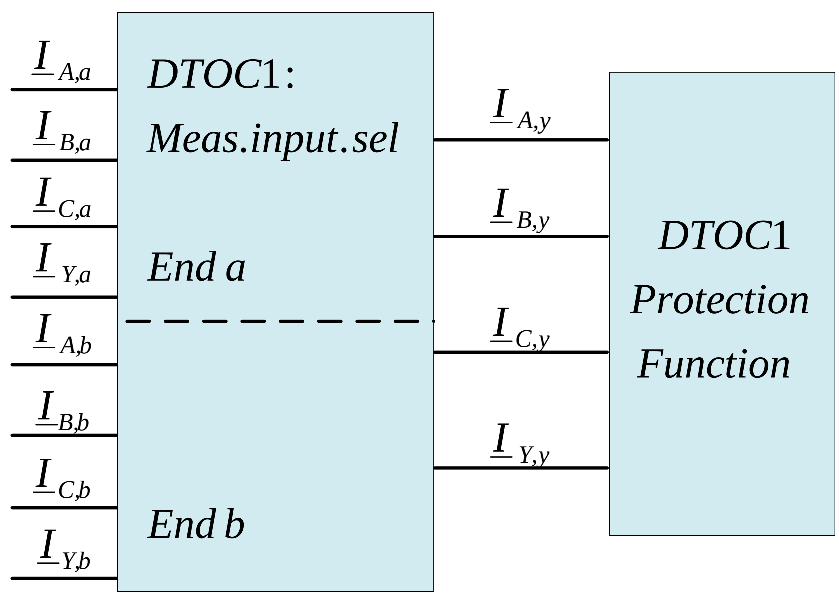


Fig. 4.8: Selection of measured values for DTOC protection

4.3.1 Enabling or Disabling DTOC Protection

DTOC protection can be enabled or disabled using setting parameters. Moreover, enabling can be carried out separately for each parameter set.

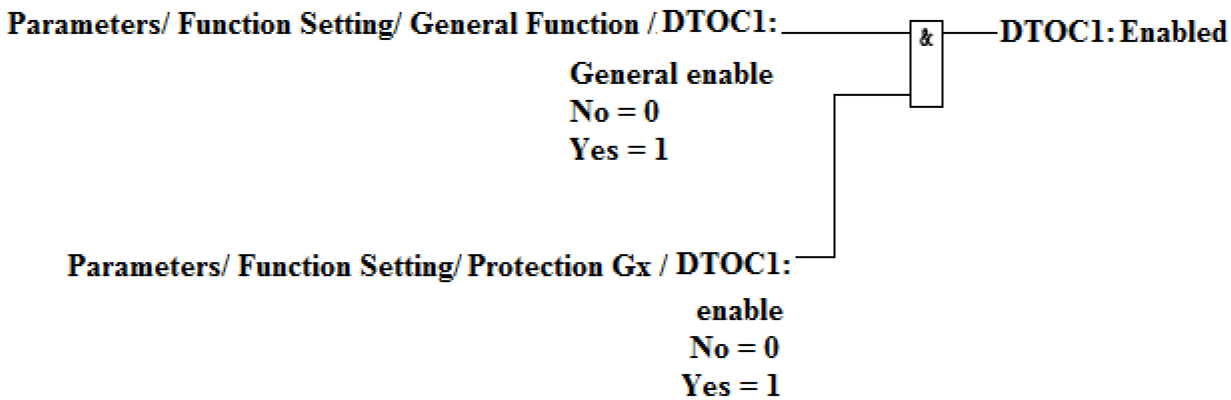


Fig. 4.11: Enabling or disabling DTOC protection

4.3.2 Phase Current Stages

The three phase currents are monitored by the HF6028 with three-stage functions to detect when they exceed the set thresholds. If the current exceeds the set thresholds in one phase, timer stages are started. Once the time delays have elapsed, a trip signal is issued. The timer stages can be blocked by appropriately configured binary signal inputs (assign DTOC1:Bl.tI>X to an input).

The first stage of the DTOC protection function can optionally be blocked by the inrush stabilization function of differential protection (Parameters/ Function Setting/ Protection Gx / DTOC1: Rush restr. Enable : Yes).

4.3.3 Negative-Sequence Current Stages

The HF6028 calculates the negative-sequence current from the three phase current values according to this equation. This is based on the setting at *Parameters/ Function Setting/ General Function / MAIN / Phase sequence*.

Phase sequence A-B-C:

$$\underline{I}_{neg} = \frac{1}{3}\left|(\underline{I}_A + \underline{a}^2\,\underline{I}_B + \underline{a}\,\underline{I}_C)\right|$$

Phase sequence A-C-B:

$$\underline{I}_{neg} = \frac{1}{3}\left|(\underline{I}_A + \underline{a}\,\underline{I}_B + \underline{a}^2\,\underline{I}_C)\right|$$

$$\underline{a} = e^{j120^\circ}$$

$$\underline{a}^2 = e^{j240^\circ}$$

The negative-sequence current is monitored by the Hf6028 with three-stage functions to detect when it exceeds the set thresholds. If the negative-sequence current exceeds the set thresholds, timer stages are started. Once the time delays have elapsed, If the operating mode of the general starting decision (*Parameters/ Function Setting/ Protection Gx / DTOC1: Gen.starting mod*) is set to "*With start. IN/Ineg"*, a trip signal is issued as well. The timer stages can be blocked by appropriately configured binary signal inputs (assign DTOC1:Bl.tng>X to an input).

The first stage of the negative-sequence current protection function can optionally be blocked by the inrush stabilization function of differential protection (*Parameters/ Function Setting/ Protection Gx / DTOC1: Rush restr. Enable*: Yes).

4.3.4 Residual Current Stages

The residual current is monitored by the Hf6028 with three-stage functions to detect when it exceeds the set thresholds. If the residual current exceeds the set thresholds, timer stages are started. Once the time delays have elapsed, a signal is issued. If the operating mode of the general starting relay (*Parameters/ Function Setting/ Protection Gx / DTOC1: Gen.starting mod*) is set to "*With start. IN/Ineg"*, a trip signal is issued as well.

The timer declaring the stages can be blocked by appropriately configured binary signal inputs (assign DTOC1:Bl.tIN>X to an input). In addition these timer stages can also be automatically blocked by single-pole or multipole starting (depending on the setting *Parameters/ Function Setting/ Protection Gx / DTOC1: Block tim,st.IN*).

4.3.5 General Starting

If the current exceeds one of the set thresholds of the phase current stages, a general starting command decision is issued. The user can select whether the starting of the negative-sequence and the residual current stages should be taken into account in the general starting decision. The general starting command triggers a stage timer. A signal is issued when the time delay of this stage has elapsed.

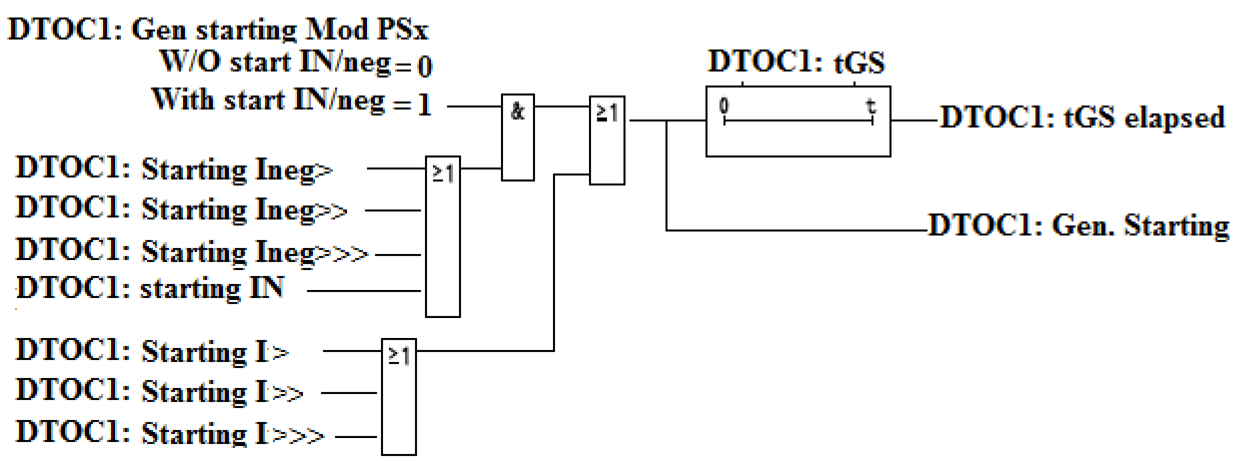


Fig. 4.12: General starting

4.4 Inverse-time Overcurrent Protection (Function Groups IDMT1 and IDMT2)

The HF6028 features an inverse-time overcurrent protection function (IDMT protection). The measured variables to be monitored by the respective IDMT function are selected by a setting parameter.

Phase current values as well as negative-sequence and residual current measured values are monitored. The function group IDMT1 will serve as an example to illustrate the operation of the IDMT protection functions. The same will apply to function group IDMT2.

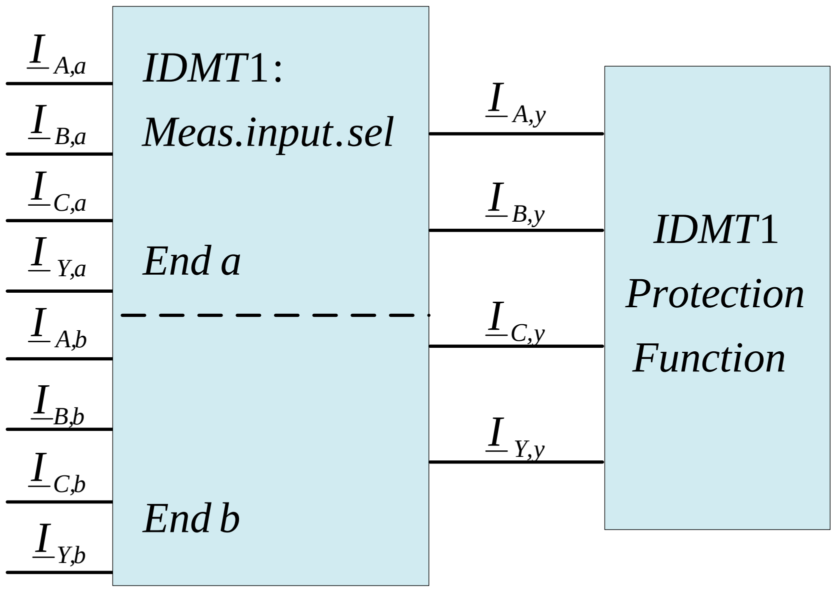


Fig. 4.13: Selection of measured variables for IDMT protection

4.4.1 Enabling or Disabling IDMT Protection

IDMT protection can be enabled or disabled via setting parameters. Moreover, enabling can be carried out separately for each parameter subset.

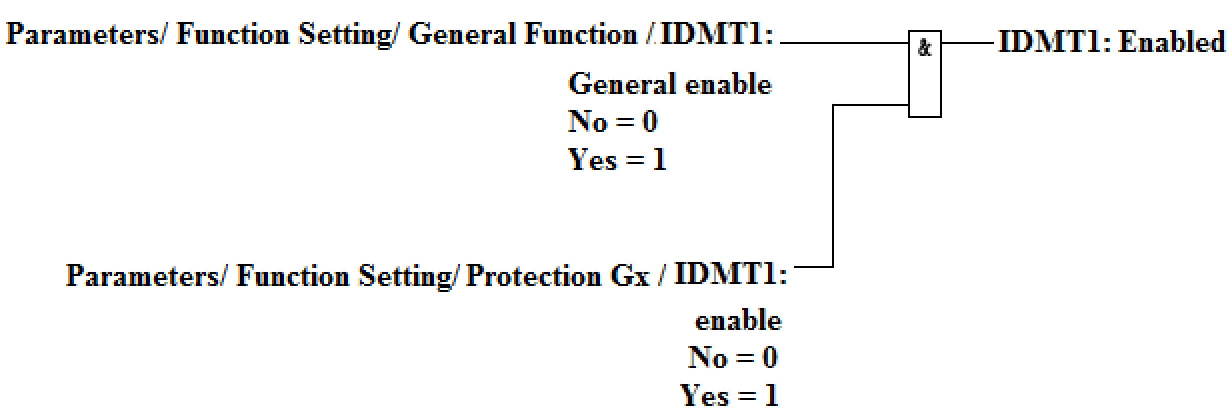


Fig. 4.14: Enabling or disabling IDMT protection

4.4.2 Time-Dependent Characteristics

The measuring systems for phase currents, residual current and negative-sequence current operate independently of each other and can be set separately. The user can select from a large number of characteristics (see table 4.4). The measured variable is the maximum phase current, the negative-sequence current, or the residual current, depending on the measuring system.

All the tripping characteristics can be calculated based on the below formula

$$t = T \times \left(\frac{K}{(I / I_s)^{\alpha} - 1} + L \right)$$

The tripping characteristics available for IEC selection are shown in the following figures (Fig. 4.15).

Table 4.4 Time Dependent characteristic

Type of Curve	Standard	K Factor	α Factor	L Factor
Standard inverse	IEC	0.14	0.02	0
Very inverse	IEC	13.5	1	0
Extremely inverse	IEC	80	2	0
Long time Inverse	IEC	120	1	0
Short time inverse	C02	0.02394	0.02	0.01694
Moderately Inverse	ANSI/IEEE	0.0515	0.02	0.114
Long time inverse	C08	5.95	2	0.18
Very inverse	ANSI/IEEE	19.61	2	0.491
Extremely inverse	ANSI/IEEE	28.2	2	0.1217
Rectifier protection	Rect	45900	5.6	0

However for RI Characteristic, the operating time can be calculated based on the below formula:

$$t = K \times \left(\frac{1}{0.339 - \frac{0.236}{(I / I_s)}} \right)$$

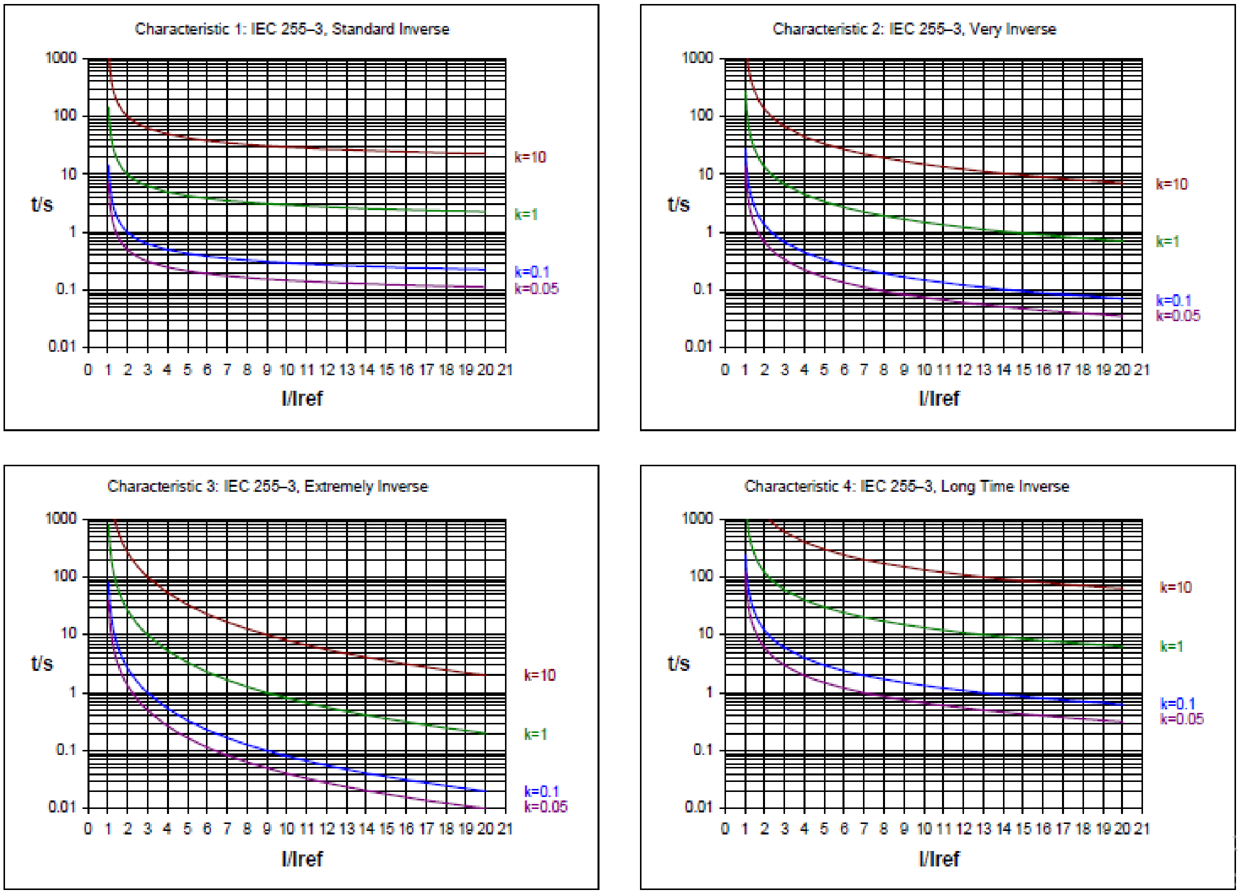


Fig. 4.15: Tripping characteristics as per IEC 255-3.

4.4.3 Phase Current Stage

The three phase currents are monitored by the HF6028 to detect when they exceed the set thresholds. The IDMT protection function will be triggered when the 1.05 times of the set reference current value is exceeded in one phase. The HF6028 will then determine the maximum current flowing in the three phases and this value is used for further processing. Depending on the characteristic selected and the current magnitude, the HF6028 will determine the tripping time. Furthermore, a minimum tripping time can be set; the tripping time will not fall below this minimum independently of the magnitude of the current.

The IDMT protection function can optionally be blocked by the inrush stabilization function of differential protection (*Parameters/ Function Setting/ Protection Gx / IDMT1: Rush restr. Enable* : Yes).

4.4.4 Negative-Sequence Current Stages

The HF6028 calculates the negative-sequence current from the three phase current values according to this equation. This is based on the setting at *Parameters/ Function Setting/ General Function / MAIN / Phase sequence*.

Phase sequence A-B-C:

$$\underline{I}_{neg} = \frac{1}{3}\left|(\underline{I}_A + \underline{a}^2\,\underline{I}_B + \underline{a}\,\underline{I}_C)\right|$$

Phase sequence A-C-B:

$$\underline{I}_{neg} = \frac{1}{3}\left|(\underline{I}_A + \underline{a}\,\underline{I}_B + \underline{a}^2\,\underline{I}_C)\right|$$

$$\underline{a} = e^{j120^\circ}$$

$$\underline{a}^2 = e^{j240^\circ}$$

The negative-sequence current is monitored by the HF6028 with three-stage functions to detect when it exceeds the set thresholds. The IDMT protection will trigger when the 1.05 times of the set reference current value is exceeded. Dependent on the characteristic selected and the negative-sequence current magnitude the HF6028 will determine the tripping time. Furthermore, a minimum tripping time can be set; the tripping time will not fall below this minimum independent of the magnitude of the current.

The negative-sequence current stage of the IDMT protection function can optionally be blocked by the inrush stabilization function of differential protection (*Parameters/ Function Setting/ Protection Gx / IDMT1: Rush restr. Enable*: Yes).

4.4.5 Residual Current Stage

The residual current is monitored by the HF6028 to detect when it exceeds the set thresholds. The IDMT protection will trigger when the 1.05 times of the set reference current value is exceeded by the residual current. Dependent on the characteristic selected and the residual current magnitude the HF6028 will determine the tripping time. Moreover the tripping time will under no circumstances fall below a settable minimum time threshold irrespective of the residual current flow magnitude.

The inverse-time stage can be blocked by an appropriately configured binary signal input (assign IDMT1:Bl.tIN>X to an input). In addition the inverse-time stage can also be automatically blocked by single-pole or multi-pole starting (depending on the setting *Parameters/ Function Setting/ Protection Gx / IDMT1: Block tim,st.IN*).

4.4.6 Hold Time

The setting of the hold time defines the time period during which the IDMT protection starting time is stored after the starting has dropped out. Should starting recur during the hold time period then the time of the renewed starting will be added to the time period stored. When the starting times sum reach the tripping time value determined by the HF6028 then the corresponding signal will be issued. Should starting not recur during the hold time period then, depending on the setting, the memory storing the accumulated starting times value will either be cleared without delay or according to the characteristic set. In Fig. 4.16, the effect of the hold time is shown by the example of a phase current stage.

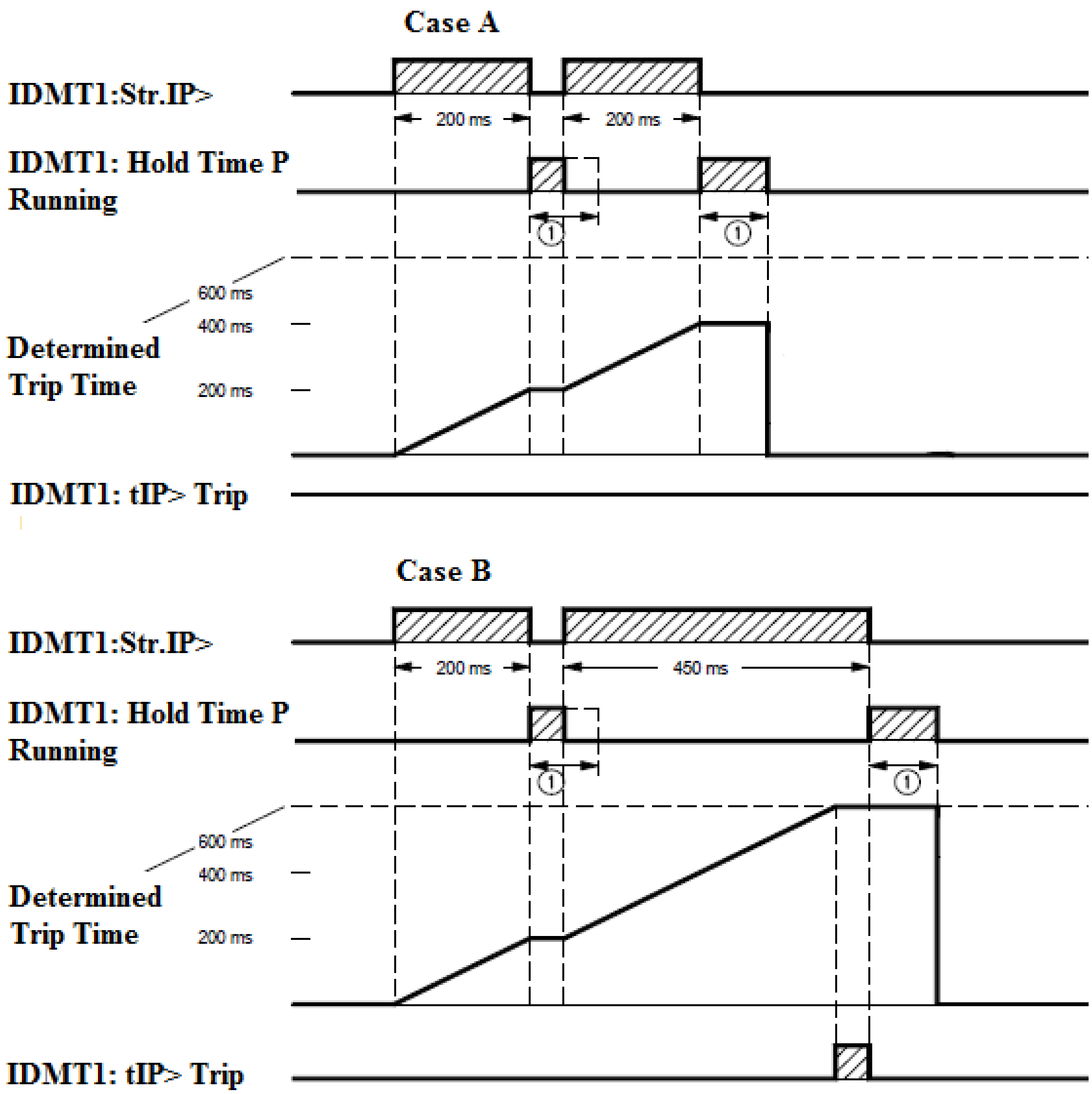


Fig. 4.16: The effect of the hold time illustrated for the phase current stage as an example: Case A: The determined tripping time is not reached, Case B: The determined tripping time is reached.

4.4.7 General Starting Command

A general starting command is triggered if the current in one phase exceeds the 1.05 times of the reference current setting. It can be selected whether the starting of the negative-sequence and residual current stages should be taken into account in the general starting decision. The general starting command triggers a stage timer. A command signal is issued when the time period of this stage has elapsed.

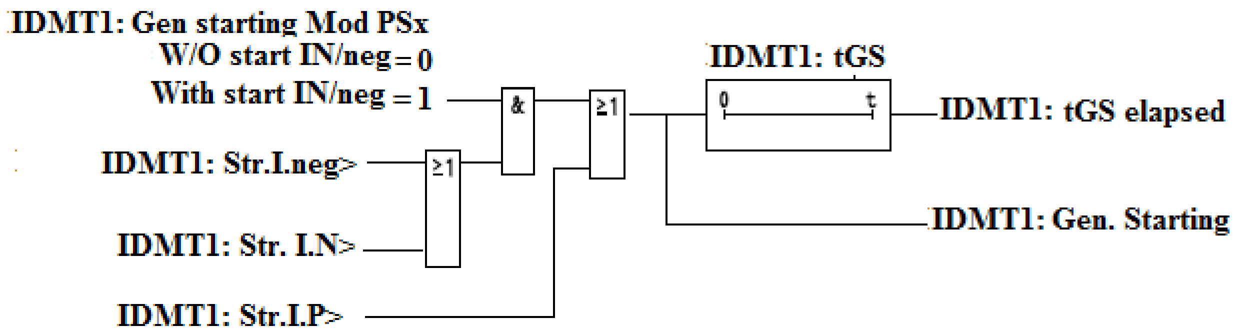


Fig. 4.17: General starting

4.5 Thermal Overload Protection (Function Group THRM)

The thermal overload protection function has been designed for overload protection of transformers. The measured values to be monitored are selected using a setting parameter.

The maximum phase current $I_{P,max}$ of the selected transformer end is used to track a first-order thermal replica according to IEC 255-8.

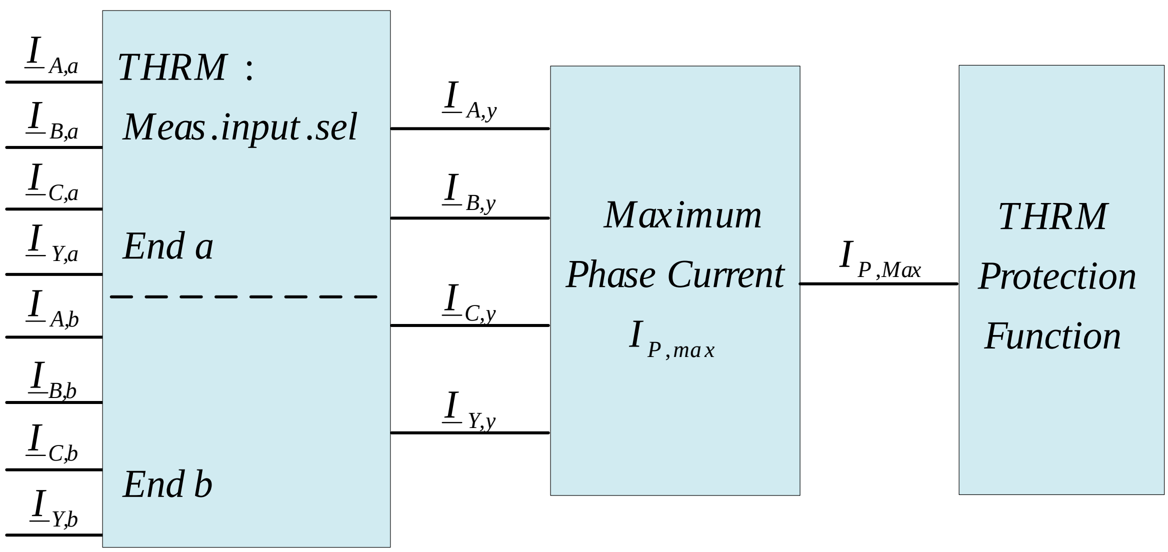


Fig. 4.18: Selection of measured values for THRM protection

4.5.1 Enabling or Disabling Thermal Overload Protection

Thermal overload protection may be enabled or disabled using setting parameters. Moreover, enabling can be carried out separately for each parameter subset.

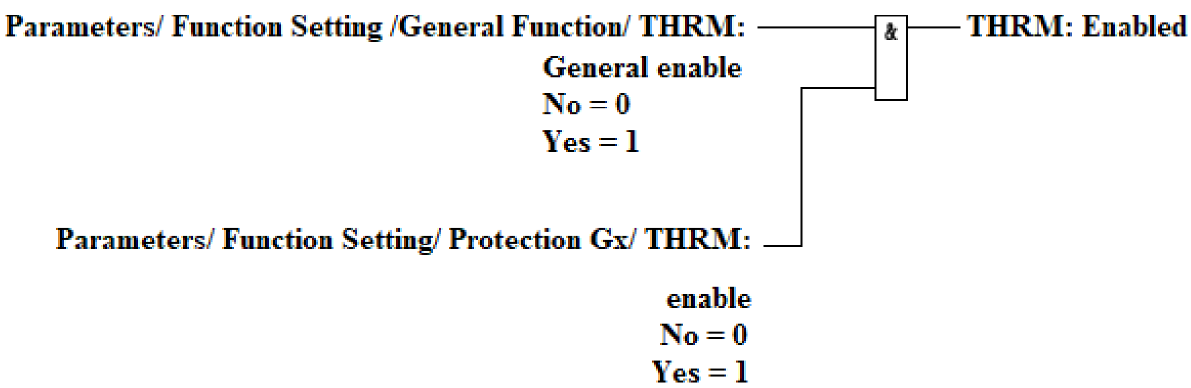


Fig. 4.19: Enabling or disabling THRM protection

4.5.2 Thermal Overload Curves

The thermal time characteristic is given by:

$$e^{(\frac{-t}{\tau})} = \frac{\left(I^2 - (C \times I_{FLC})^2\right)}{(I^2 - I_P^2)}$$

Where:

t	=	the iteration cycle time (100 ms)
τ	=	Heating and cooling time constant of the protected equipment
I	=	Largest phase current
I_{FLC}	=	Full load current rating (relay setting 'Thermal Trip')
C	=	1.05 constant, allows continuous operation up to < 1.05 IFLC
I_P	=	Steady state pre-loading current before application of the overload

The calculation of the thermal state is given by the following formula:

$$\theta_{i+1} = \left(\frac{I_{eq}}{K \times I\theta >}\right)^2 \left[1 - e^{(\frac{-t}{T_e})}\right] + \theta_i \, e^{(\frac{-t}{T_e})}$$

θ being calculated every 100ms.

Where:

T_e	=	The time constant of the transformer. As a function of the operating conditions of the transformer, the relay uses one of the following 2 thermal time constants:

- The heating time constant T_H, used when the equivalent thermal current I_{eq} is greater than 0.1 Iθ>.
- The cooling time constant Tc, used when the equivalent thermal current I_{eq} is below the 0.1 Iθ >, i.e. when the transformer is in the no-load condition.

I_{eq}	=	Equivalent current corresponding to the RMS value of the largest phase current
$I\theta>$	=	Full load current rating given by the national standard or by the supplier
K	=	Factor associated to the thermal state formula
θ_i	=	the value of the thermal state calculated above (100ms before)

The setting for the operating mode selects an “absolute” or “relative” replica. If the setting is for “Absolute replica”, the HF6028 will operate with a fixed trip threshold θ_{trip} of 100 %.

The time to trip varies depending on the load current carried before application of the overload, i.e. whether the overload was applied from "hot" or "cold".
The mathematical formula applicable to HF6028 is the following

$$t_{Trip} = T_e \; Ln \left[\frac{I_{th}^2 - \theta_0}{I_{th}^2 - \theta_{Trip}}\right]$$

Where:

I_{th}	=	$I_{eq}/(K \times I\theta>)$
θ_0	=	Initial thermal state. If the initial thermal state = 30% then θ =0.3
θ_{Trip}	=	Trip thermal state. If the trip thermal state is set at 100%, then $\theta_{Trip} = 1$
θ_{Alarm}	=	Alarm thermal state. If the alarm thermal state is set at 90%, then $\theta_{Alarm} = 0.9$

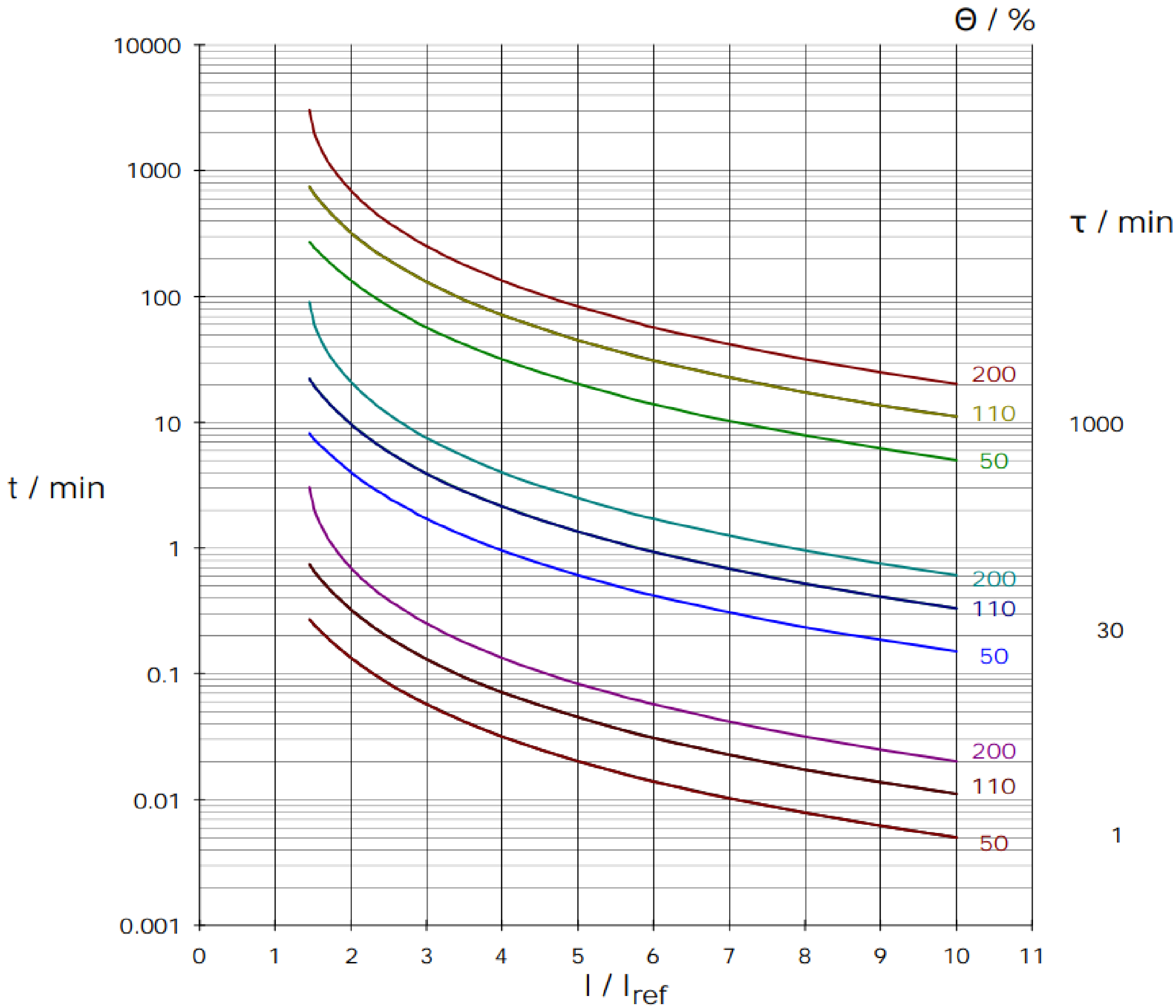


Fig. 4.20: Tripping characteristic of the thermal overload protection

Tripping characteristics apply to θ_0 = 0 % and identical settings for the maximum permissible coolant and the updated measurement of the object temperature.

4.5.3 Thermal Parameter K-factor

The thermal protection is set in reference values. The nominal current Inom CT of the protected Transformer is used as the basic current for thermal protection.

The Thermally permissible continuous current for the transformer is known from the manufacturer's specifications. For the THRM: K PSX to be set in the device the following applies.

$$K = \frac{I_{max,permissible}}{I_{ref}} \times \frac{I_{ref}}{I_{nom\ CT\ ,pri}}$$

Where:

$I_{max,\ permissible}$	=	Permissible thermal current of transformer (enda or endb)
I_{ref}	=	Nominal current of the transformer
$I_{nom\ CT,\ pri}$	=	Nominal Primary CT current

Example: Transformer and CT with the following data:

Permissible Continuous Current	$I_{max,\ permissible} = 1.2 \times Iref$
Nominal Transformer Current	$I_{ref} = 1100$ A
Current Transformer (CT)	1200 A/1 A

Setting value FACTOR *K*:

$$K = 1.2 \times \frac{1100\ A}{1200\ A} = 1.1$$

4.6 Current Transformer Supervision (CTS)

Current Transformer Supervision (CTS) is based on the measurement of the ratio of I2/I1 at two ends. When this ratio is not zero, one of the following two conditions may be present:

- An unbalanced fault is present on the system - both I2 and I1 are non-zero.
- There is a 1 or 2 phase CT problem - both I2 and I1 are non-zero.

If the I2/I1 ratio is greater than the set value, CTS I2/I1>2, at two ends, it is almost certainly a genuine fault condition (CTS I2/I1>2 set above maximum unbalanced load and below the minimum unbalanced fault current). Therefore, CTS will not operate. If this ratio is detected at one end only, one of the following conditions may be present:

- A CT problem
- A single end fed fault condition

I1 is used to confirm whether it is a CT problem or not. If I1 > CTS I1 is detected at two ends, it must be a CT problem and CTS is allowed to operate. If this condition (I1 > CTS I1) is detected at only one end, it is assumed that either an inrush condition or a single end fed internal fault is present. Therefore, the CTS operation is blocked.

The CTS status under the CT SUPERVISION sub-heading can be set either as indication or restraint. In indication mode if a CT failure is present, an alarm would be issued, but the differential protection would remain unrestricted. Therefore, the risk of unwanted tripping under load current is present. In restraint mode, the differential protection is blocked for 20 ms after CT failure has been detected. Then the new setting Is-CTS is applied to the differential protection, as shown in Figure 4.21, the restraint region of the bias characteristic increases. The low impedance REF, earth fault and NPS overcurrent protections are internally blocked by CTS when a CT failure is detected in the CT used by each protection function. Earth fault protection is immune to CTS blocking if IN> input is set to measured.

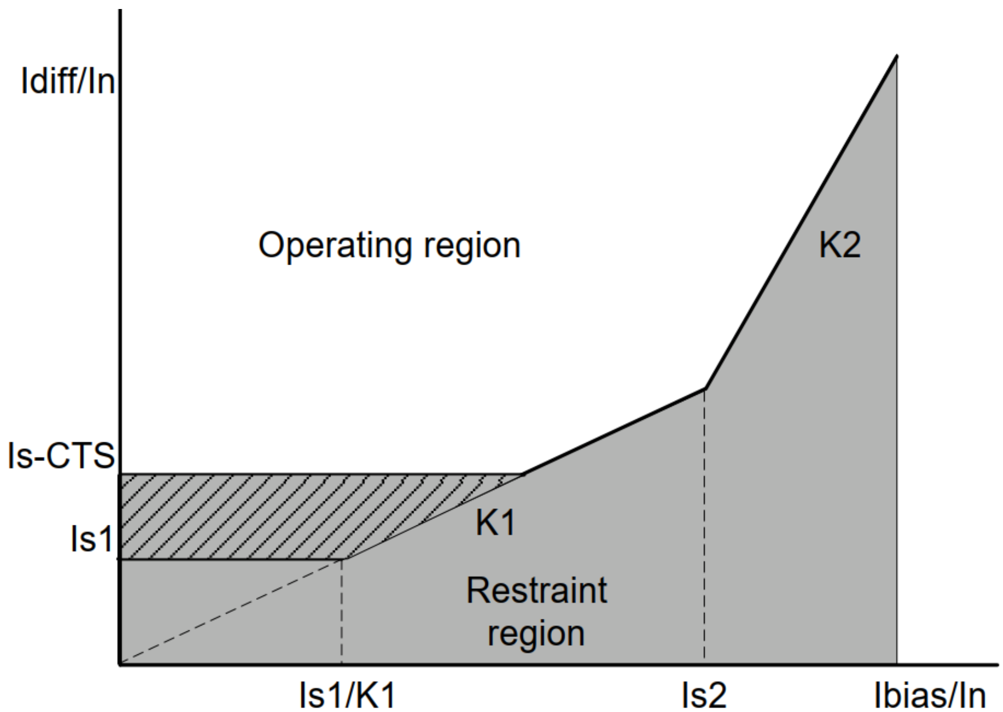


Figure 4.21: CTS I1 setting applied to the differential protection

A faulty CT is determined if the following conditions are present at the same time:

- The positive sequence current in at least two current inputs exceeds the set release threshold I1 (CTS I1 setting under the differential menu). This also means that CTS can only operate if minimum load current of the protected object is present.
- On exactly one end a high set ratio of negative to positive sequence current, CTS I2/I1>2, is exceeded.
- On one other end the ratio of negative to positive sequence current is less than a low set value, CTS I2/I1> 1, or no significant current is present (positive sequence current is below the release threshold I1)

Only a single or double phase CT failure can be detected by this logic. The probability of symmetrical three-phase CT failures is very low, therefore in practice this is not a significant problem.

5 DESIGN STRUCTURE

The LAPCO HF6028 has a fixed local control panel. The local control panel is covered with a tough film so that the specified degree of IP protection will be maintained. In addition to the essential control and display elements, a parallel display consisting of multi-colored LED indicators is also incorporated. The meaning of the various LED indications is shown in plain text on a label strip.

The PC interface (9-pin D-Sub female connector) is located under the hinged cover at the bottom of the local control panel.

5.1.1 Designs Information

The LAPCO HF6028 is available in a flush-mounted case with ring-terminal connection. These terminals in the flush-mounted case is connected at the back of the case.

Warning!

The secondary circuit of live system current transformers must not be opened!

If the secondary circuit of a live CT is opened, there is a serious danger that the resulting voltages will endanger personnel and damage the CT insulation.

5.1.2 Dimensional Drawings

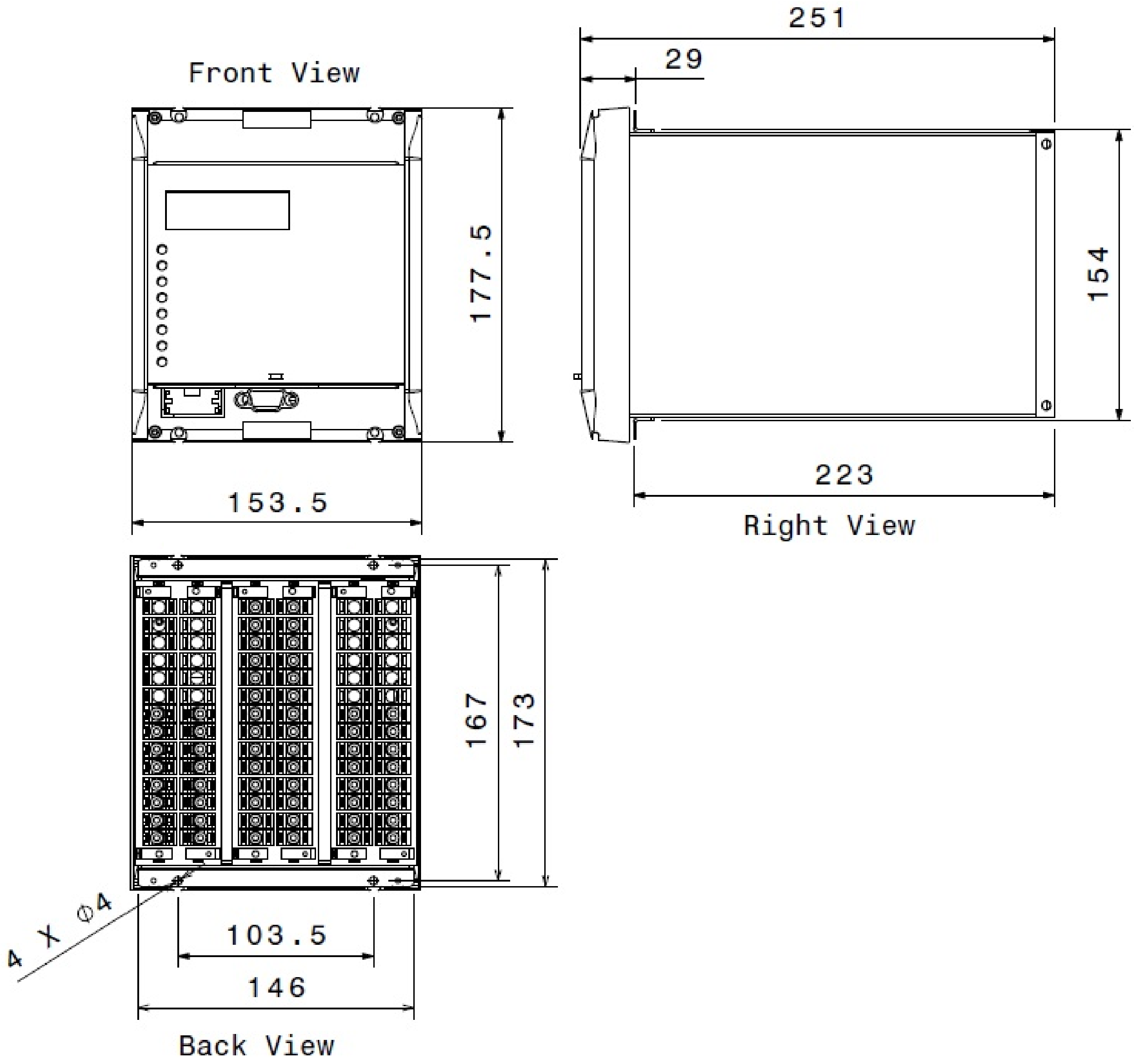


Fig. 5.1: Flush-mounted case 6 inch. (Dimensions in mm.)

6 RELAY INSTALLATION AND WIRINGS

Warning!

Sustained exposure to high humidity during storage may cause damage to electronics and reduce the lifetime of the equipment.

We recommend that storage humidity shall not exceed 50% relative humidity. Once the LAPCO HF6028 has been unpacked, we recommend that they are energized within the three following months.

Where electrical equipment is being installed, sufficient time should be allowed for acclimatization to the ambient temperature of the environment, before energization.

Warning!

Only qualified personnel, familiar with the "Warning" page at the beginning of this manual, may work on or operate this device.

Warning!

Check that the protective ground connection is secured with a tooth lock washer.

6.1 Unpacking and Packing

All LAPCO HF 6028 devices are packaged separately into dedicated cartons and shipped with outer packaging. Use special care when opening cartons and unpacking devices, and do not use force. In addition, make sure to remove supporting documents and the type identification label supplied with each individual device from the inside carton. After unpacking, each device should be inspected visually to confirm it is in proper mechanical condition.

6.2 Checking Nominal Data and Design Type

The nominal data and design type of the LAPCO HF6028 can be determined by checking the type identification label (see below). One type identification label is located under the upper hinged cover on the front panel.

HF 6028 3A8xxE01
SN: 21/xx/xxxxxx In: 1/5 A
Vx: 48-150 Vdc/ 48-130 Vac

Fig. 6.1: Example of the type identification label of a LAPCO HF6028 device.

The LAPCO HF6028 design version can be determined from the order number. A breakdown of the order number is given in Chapter "Order Information" of this manual.

6.3 Relay Installation Location Requirements

The LAPCO HF6028 has been designed to conform to EN 60255-6. Therefore it is important when choosing the installation location to make certain that it provides the operating conditions as specified in above DIN norm sections 3.2 to 3.4. Several of these important operating conditions are listed below.

6.3.1 Environmental Conditions

Ambient temperature:	-5 °C to +55 °C [+23 °F to +131 °F]
Air pressure:	800 to 1100 hPa
Relative humidity:	The relative humidity must not result in the formation of either condensed water or ice in the LAPCO HF6028.
Ambient air:	The ambient air must not be significantly polluted by dust, smoke, gases or vapors, or salt.
Solar Radiation:	Direct solar radiation on the front of the device must be avoided to ensure that the LC-Display remains readable

6.3.2 Mechanical Conditions

Vibration stress:	-10 to 60 Hz, 0.035 mm and 60 to 150 Hz, 0.5 g
Earth quake resistance:	5 ... 8 Hz, 3.5 mm / 1.5 mm, 8 ... 35 Hz, 5 m/s², 3 x 1 cycle

6.3.3 Electrical Conditions for Auxiliary Voltage of the Power Supply

Operating range:	0.9 to 1.1 $VA_{nominal}$ with a residual ripple of up to 12 % $VA_{nominal}$

6.3.4 Electromagnetic Conditions

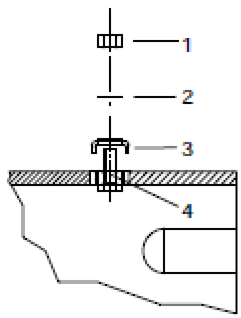
Substation secondary system design must follow the best of modern practices, especially with respect to grounding and EMC.

6.4 Protective and Operational Grounding

The device must be reliably grounded to meet protective equipment grounding requirements. The surface-mounted case is grounded using the bolt and nut, appropriately marked, as the ground connection. The flush-mounted case must be grounded in the area of the rear sidepieces at the location provided.

The bracket is marked with the protective ground symbol.

The cross-section of the ground conductor must conform to applicable national standards. A minimum cross section of 2.5 mm² (≤ AWG12) is required. All grounding connections must be low-inductance, i.e. it must be kept as short as possible.



flush-mount. case	
Pos.	Description
1	Nut M4
2	Tooth lock wash.A4.3
3	Clamp bracket
4	Bolt M4

Fig. 6.2: Installing the protective grounding conductor terminal.

The protective conductor (earth) must always be connected to the protective grounding conductor terminal in order to guarantee the safety given by this setup.

6.5 Relay Terminals Connection procedure

The LAPCO HF6028 Transformer Differential Protection Device must be connected in accordance with the terminal connection diagram as indicated on the type identification label. The relevant terminal connection diagrams that apply to the LAPCO HF6028 are to be found in the supporting documents supplied with the device, or in Fig. 2.2.

In general copper conductors with a cross section of 2.5 mm² (US: AWG12) are sufficient to connect a system current transformer to a current input on the LAPCO HF6028. To reduce CT knee-point voltage requirements, it may be necessary to install shorter copper conductors with a greater cross section between the system current transformers and the current inputs on the LAPCO

HF6028. Copper conductors having a cross section of 1.5 mm² (US: AWG14) are adequate to connect binary signal inputs, the output relays and the power supply input.

All connections run into the system must always have a defined potential. Connections that are pre-wired but not used should preferably be grounded when binary inputs and output relays are isolated. When binary inputs and output relays are connected to common potential, the pre-wired but unused connections should be connected to the common potential of the grouped connections.

6.5.1 Method of Relay Measuring and Auxiliary circuits Connection

6.5.1.1 Power Supply

Before connecting the auxiliary voltage VA for the LAPCO HF6028 power supply, it must be ensured that the nominal value of the auxiliary device voltage corresponds with the nominal value of the auxiliary system voltage.

6.5.1.2 Current-Measuring Inputs

When connecting the system transformers, it must be ensured that the secondary nominal currents of the system and the device correspond.

Warning!

The secondary circuit of live system current transformers must not be opened!

If the secondary circuit of a live CT is opened, there is the danger that the resulting voltages will endanger personnel and damage the insulation.

6.5.1.3 Connecting the Measuring Circuits

The system current transformers must be connected in accordance with the standard schematic diagram shown in Fig. 6.3. It is essential that the grounding configuration shown in the diagram be followed. If the CT connection is reversed, this can be taken into account when making settings.

6.5.1.4 Connecting Binary Inputs and Output Relays

The binary inputs and output relays are freely configurable. When configuring these components it is important to note the contact rating of the binary I/O modules.

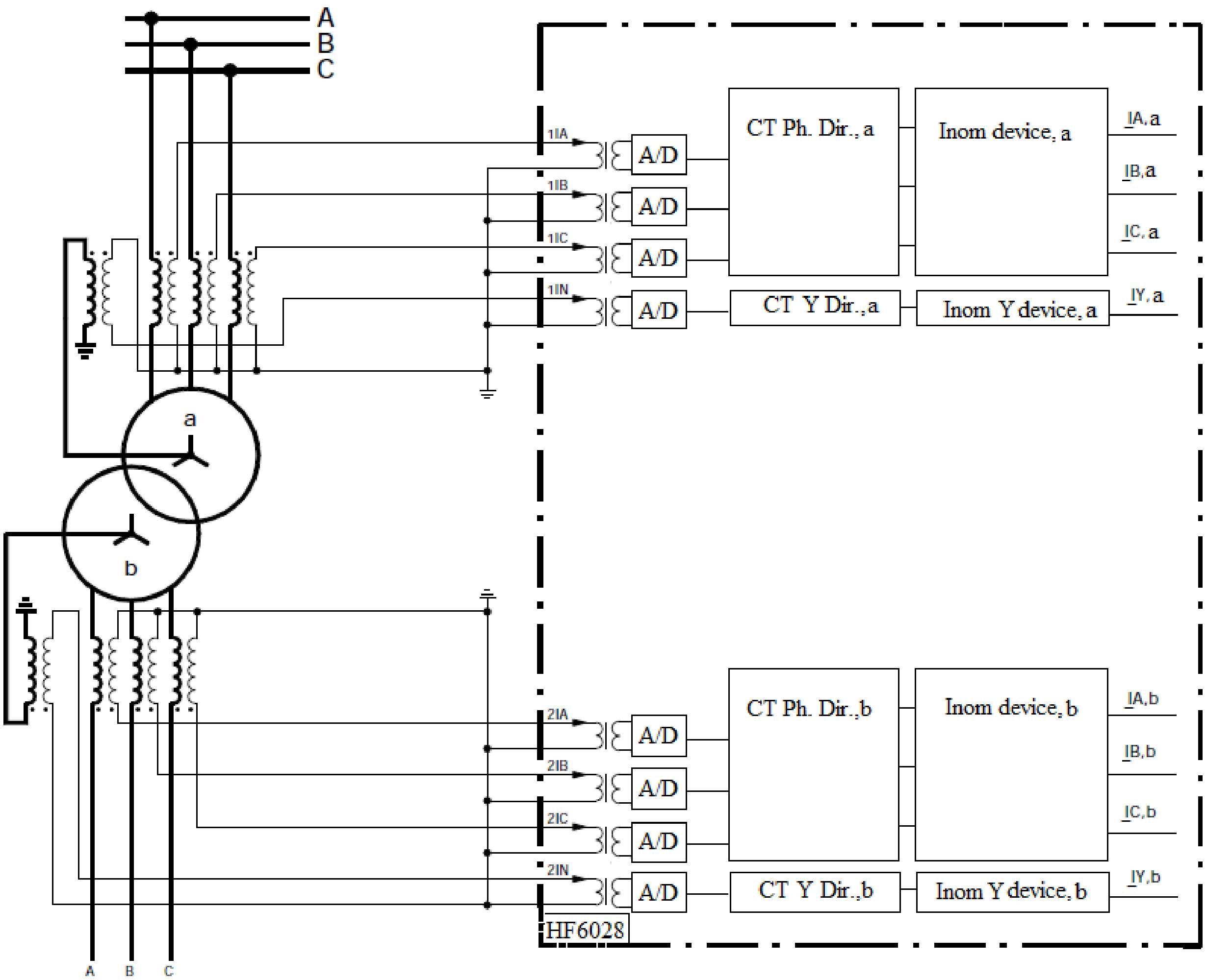


Fig. 6.3: Standard schematic connection diagram for the LAPCO HF6028

6.5.2 Connecting the Serial Interfaces

6.5.2.1 PC Interface

The PC interface is provided so that personnel can operate the device from a personal computer (PC).

Warning!

The PC interface is not designed as a permanent connection. Consequently, the female connector does not have the extra insulation from circuits connected to the system that is required per VDE 0106, part 101.

6.5.2.2 Communication Interfaces

The communication interfaces are provided as a permanent connection of the device to a control system for substations or to a central substation unit. The communication interface 1 on the device is connected by an RS 485 interface with twisted pair copper wires.

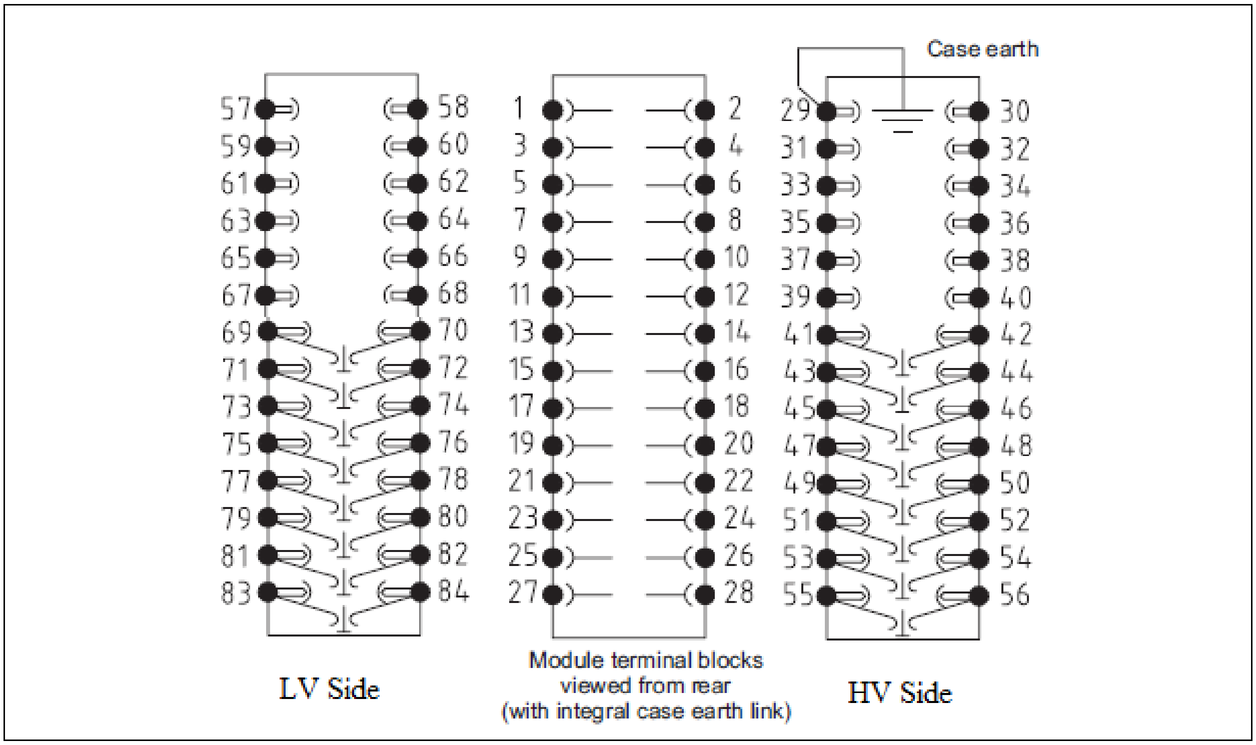
Warning!

An RS 485 data transmission link between a master and several slave devices can be established by using the optional communication interface. The communication master could be, for instance, a central control station. Devices linked to the communication master, e.g. LAPCO HF6028, are set-up as slave devices.

The RS 485 interface available on the HF6028 was designed so that data transfer in a full duplex transmission mode is possible using a 4-wire data link between devices. Data transfer between devices using the RS 485 interface is set up only for a half-duplex transmission mode. To connect the RS 485 communication interface the following must be observed:

- Only twisted pair shielded cables must be used, that are common in telecommunication installations.
- At least one symmetrical twisted pair of wires is necessary.
- Conductor insulation and shielding must only be removed from the core in the immediate vicinity of the terminal strips and connected according to national standards.
- All shielding must be connected to an effective protective ground surface at both ends.
- Unused conductors must all be grounded at one end.

7 LOCATION AND CONNECTION DIAGRAM



Input 7 +	57	58	Input 6 +
Input 7 –	59	60	Input 6 –
	61	62	Terminal RS485
	65	66	
	67	68	
Current input IA (5A)	69	70	Current input IA (5A)
Current input IB (5A)	71	72	Current input IB (5A)
Current input IC(5A)	73	74	Current input IC(5A)
Current input Ie (5A)	75	76	Current input Ie (5A)
Current input IA (1A)	77	78	Current input IA (1A)
Current input IB (1A)	79	80	Current input IB (1A)
Current input IC(1A)	81	82	Current input IC(1A)
Current input Ie (1A)	83	84	Current input Ie (1A)

Output 5	1	2	Common output 1
Common output 5	3	4	Output 1 (NC)
Output 6	5	6	Output1 (NO)
Common output 6	7	8	Common output 2
Common output 7	9	10	Output 2 (NC)
Output 7	11	12	Output 2 (NO)
Common output 8	13	14	Output 3
Output 8	15	16	Common output 3
Input 3 +	17	18	Output 4
Input 3 –	19	20	Common output 4
Input 4 +	21	22	Input 1 +
Input 4 –	23	24	Input 1 –
Input 5 +	25	26	Input 2 +
Input 5 –	27	28	Input 2 –

Case earth connection	29	30	Terminal RS485
RS485 -	31	32	RS485+
Vaux +	33	34	Vaux –
Relay failed	35	36	Common "Watchdog"
Relay healthy	37	38	
	39	40	
Current input IA (5A)	41	42	Current input IA (5A)
Current input IB (5A)	43	44	Current input IB (5A)
Current input IC(5A)	45	46	Current input IC(5A)
Current input Ie (5A)	47	48	Current input Ie (5A)
Current input IA (1A)	49	50	Current input IA (1A)
Current input IB (1A)	51	52	Current input IB (1A)
Current input IC(1A)	53	54	Current input IC(1A)
Current input Ie (1A)	55	56	Current input Ie(1A)

8 LOCAL CONTROL (HMI)

8.1 Local Control Panel (HMI)

All the data required for operation of the protection device is entered from the local control panel, and the data important for system management is read out there as well. The following tasks can be handled from the local control panel:

- Readout and modification of settings
- Readout of cyclically updated measured operating data and logic status signals
- Readout of faults information after faults inception in the power system
- Readout of alarm logs after faults inception in the power system
- Readout of faults information after faults inception in the power system
- Device resetting and triggering of additional control functions used in testing and commissioning

Control is also possible through the PC interface. This requires a suitable PC and a specific operating program.

8.2 Display and Keypad

8.2.1 Text Display

The local control panel as a text display includes an LC display containing 2 × 1 alphanumeric characters. There are seven keys with permanently assigned functions situated below the LCD. Furthermore the local control panel (HMI) is provided with 8 LED indicators.

8.2.2 Display Illumination

If none of the control keys are pressed, the display light turns off after one minute. Pressing any of the control keys will turn the display illumination on again. In this case the control action that is normally triggered by that key will not be executed.

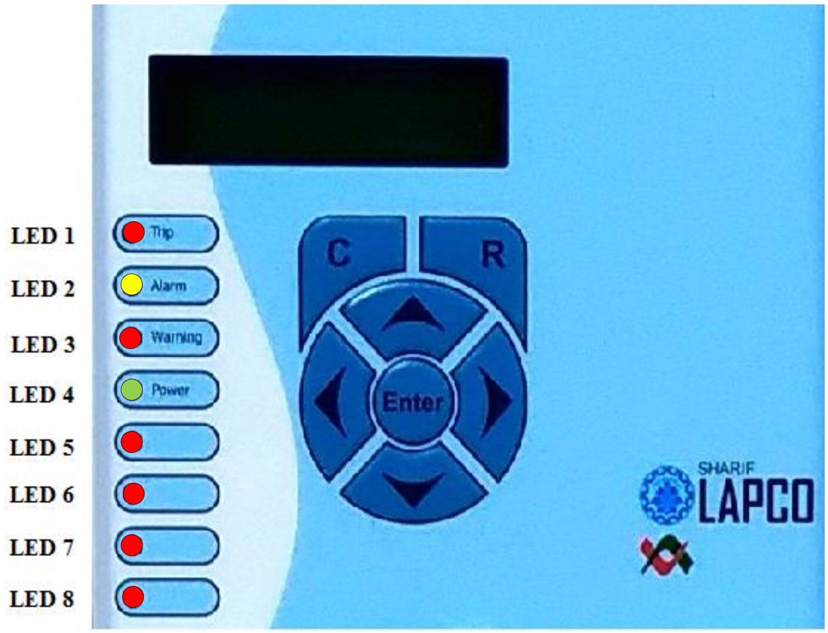


Fig. 8.1: View of the local control panel and layout of the LED indicators for the text display

8.2.3 Short Description of Keys

- **"Up" and "Down" Keys**

Panel Level: The "up"/"down" keys switch between the pages of the Measured Value Panel.

Menu Tree Level: Press the "up" and "down" keys to navigate up and down through the menu tree in a vertical direction. If the unit is in input mode, the "up" and "down" keys have a different function.

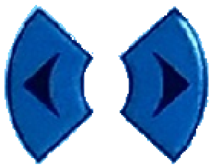
Input mode: Press the "up" and "down" keys in this mode to change the setting value.

● "Up" key: the next higher value is selected.

● "Down" key: the next lower value is selected.

With list settings, press the "up" and "down" key to change the logic operator of the value element.

“Left” and “Right” Keys



Menu Tree Level: Press the “left” and “right” keys to navigate through the menu tree in a horizontal direction. If the unit is in input mode, the “left” and “right” keys have a different function.

Input mode: When the “left” and “right” keys are pressed, the cursor positioned below one of the digits in the change-enabled value moves one digit to the right or left.

- “Left” key: the cursor moves to the next digit on the left.
- “Right” key: the cursor moves to the next digit on the right.

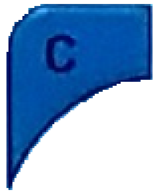
In the case of a list setting, press the “left” and “right” keys to navigate through the list of items available for selection.

“Enter” Keys

Menu Tree Level: Press the ENTER key at the Panel level to go to the menu tree.

Input mode: Press the ENTER key to enter the input mode. Press the ENTER key a second time to accept the changes as entered and exit the input mode.

“Clear” Keys



Press the CLEAR key to reset the LED indicators and clear all measured event data. The records in the recording memories are not affected by this action.

Input mode: When the CLEAR key is pressed all changes entered are rejected.

- **“Read” Keys**

Press the READ key to access a selected event recording from either the Panel level or from any other point in the menu tree.

8.3 Display Levels

All data relevant for operation and all device settings are displayed on two levels. At the Panel level, data such as measurements are displayed in Panels that provide a quick overview of the current state of the bay. The *“menu tree”* level below the panel level allows the user to select all data points (settings, signals, measured variables, etc.) and to change them, if appropriate. To access a selected Alarm recording from either the panel level or from any other point in the menu tree, press the “READ” key.

8.4 Menu Tree and Data Points

All *data points* (setting values, signals, measured values, etc.) are selected using a *menu tree*. The name of the parameters is shown in the first line of the LC-Display. The *data points* are found at the lowest level of a *menu tree* branch and they are displayed either with their plain text description or in numerically encoded form. The value associated with the selected *data point*, its meaning, and its unit of measurement are displayed in the line below. The menu tree is shown in the LAPCO HF6028 Menu Guide.pdf.

9 SETTINGS

9.1 Parameters

The LAPCO HF6028 must be adjusted to the system and to the protected equipment by appropriate settings. This chapter gives instructions for determining the settings, which are located in the folder titled “Parameters” in the menu tree. The sequence in which the settings are listed and described in this chapter corresponds to their sequence in the menu tree.

The LAPCO HF6028 devices are supplied with a factory-set standard configuration of settings that, in most cases, correspond to the default settings.

General Notes on the Configuration of the LED Indicators

The LAPCO HF6028 has LED indicators for parallel display of binary signals. LED 4 is not configurable. It is labeled “HEALTHY” and signals the operational readiness of the protection unit (supply voltage present). The color of LED 4 is green. LED 2 and 3 are not configurable either. LED 3 is labeled “WARNING” and signals a blocking or malfunction; the color of LED 3 is red and indicates that the HF6028 is blocked or data is being transmitted form PC to the HF6028. LED 2 is labeled “ALARM” and signals an alarm.

“Configuration and Operating Mode of the LED Indicators (Function Group LED)” in Chapter “Operation” describes the layout of the LED indicators and the factory setting for LED 1. It is labeled “Trip” and always works in latched mode. The color of LED 1 is red.

An operating mode can be defined for each LED indicator. Depending on the set operating mode, the LED indicator will operate in either latching or non-latching mode. For LED indicators operating in latching mode, the operating mode setting also determines when latching will be cancelled.

With the multi-color LED indicators (H 5 – H 8) the colors red and green can be independently assigned with functions. The third color amber results as a mixture of red and green, i.e. when both functions assigned to the LED indicator are simultaneously present.

9.1.1 Device Identification

The device identification settings are used to record the ordering information and the design version of the LAPCO HF6028. They have no effect on the device functions. These settings should only be changed if the design version of the LAPCO HF6028 is modified.

Table 9.1 Device ID Setting

Parameter Default	 Min	 Max	 Unit
Device Type			
6028	6028	6028	
The device type is displayed. This display cannot be altered.			
Software Version			
Not Measured	00.00	99.99	
Device Address			
1	1	255	
device addresses are used to address the device in communication via the PC interface. An identical setting must be selected for both addresses.			

9.1.2 Configuration Parameters

Table 9.2 Binary and Analog Output Setting

Parameter Default	 Min	 Max	 Unit
Relay Assignm. 1			
Without function			
Relay Assignm. 2			
Without function			
Relay Assignm. 3			
Without function			
Relay Assignm. 4			
Without function			
Relay Assignm. 5			
Without function			
Relay Assignm. 6			
Without function			
Relay Assignm. 7			
Without function			
Relay Assignm. 8			
Without function			
Assignment of functions to output relays.			
Op. Mode Output1			
Unlatched			
Op. Mode Output2			
Unlatched			
Op. Mode Output3			
Unlatched			
Op. Mode Output4			
Unlatched			
Op. Mode Output5			
Unlatched			

Op. Mode Output6
Unlatched
Op. Mode Output7
Unlatched
Op. Mode Output8
Unlatched
Selection of operating mode for output relays.

Table 9.3 Binary Input Setting

Parameter **Default** **Min** **Max** **Unit**
Input Assignm. 1
Without function
Input Assignm. 2
Without function
Input Assignm. 3
Without function
Input Assignm. 4
Without function
Input Assignm. 5
Without function
Input Assignm. 6
Without function
Input Assignm. 7
Without function
Assignment of functions to output relays.
Op. Mode Output1
Active “High”
Op. Mode Output2
Active “High”
Op. Mode Output3
Active “High”
Op. Mode Output4
Active “High”
Op. Mode Output5
Active “High”
Op. Mode Output6
Active “High”
Op. Mode Output7
Active “High”
Selection of operating mode for output relays.

Table 9.4 LED Indicators Setting

Parameter **Default**	**Min**	**Max**	**Unit**	
LED 1 Red				
Main Gen. Trip				
This LED always operates as Latched mode.				
LED 2 Yellow				
alarm				
This LED is not configurable. This blinking LED indicates alarm signals.				
LED 3 Red				
Warning				
This LED is not configurable. The function **Blocked/faulty** is permanently assigned. This LED indicates that the relay is blocked.				
LED 4 Green				
Healthy				
This LED is not configurable and displays the operational readiness of the protection device. The function **Healthy** is permanently assigned.				
LED 5 Red				
Without function				
LED 5 Green				
Without function				
LED 6 Red				
Without function				
LED 6 Green				
Without function				
LED 7 Red				
Without function				
LED 7 Green				
Without function				
LED 8 Red				
Without function				
LED 8 Green				
Without function				
Assignment of functions to LED indicators.				
Op. Mode LED 5				
Unlatched				
Op. Mode LED 6				
Unlatched				
Op. Mode LED 7				
Unlatched				
Op. Mode LED 8				
Unlatched				
Selection of operating mode for LED indicators.				

9.1.3 Function Setting

9.1.3.1 Global

Table 9.5 MAIN Function Setting

Parameter Default	Min	Max	Unit
Assig.trip cmd.1			
Without function			
Assignment of signals that trigger trip command 1.			
Assig.trip cmd.2			
Without function			
Assignment of signals that trigger trip command 2.			
Assig.trip cmd.3			
Without function			
Assignment of signals that trigger trip command 3.			
Assig.trip cmd.4			
Without function			
Assignment of signals that trigger trip command 4.			
Latch trip cmd. 1			
No			
Specification as to whether trip command 1 should latch.			
Latch trip cmd. 2			
No			
Specification as to whether trip command 2 should latch.			
Latch trip cmd. 3			
No			
Specification as to whether trip command 3 should latch.			
Latch trip cmd. 4			
No			
Specification as to whether trip command 4 should latch.			
Min. dur. trip 1			
0.25	0.10	10.00	s
Setting for the minimum duration of trip command 1.			
Min. dur. trip 2			
0.25	0.10	10.00	s
Setting for the minimum duration of trip command 2.			
Min. dur. trip 3			
0.25	0.10	10.00	s
Setting for the minimum duration of trip command 3.			
Min. dur. trip 4			
0.25	0.10	10.00	s
Setting for the minimum duration of trip command 4.			

Table 9.6 Fault Recording Setting

Parameter Default	Min	Max	Unit
Rec. Trigger Assign			
Without function			
This setting defines the signals that will trigger fault recording.			
Pre-fault Time			
0.1	0.1	3.0	s
Setting for the time during which data will be recorded before the onset of a fault (pre-fault recording time).			
Post-fault Time			
0.1	0.1	3.0	s
Setting for the time during which data will be recorded after the end of a fault (post-fault recording time).			
Max. Record Time			
0.1	0.1	3.0	s
Setting for the maximum recording time per fault. This includes pre-fault and post-fault recording times.			

Table 9.7 Parameter Subset Selection Setting

Parameter Default	Min	Max	Unit
Param.Sub.Sel			
Active Setting 1			

9.1.3.2 General Functions

Table 9.8 Main Function Setting

Parameter **Default**	**Min**	**Max**	**Unit**
Protection Enabled			
Yes(=On)			
(Device on-line) Switching the device off-line or on-line. Some parameters can only be changed when protection is disabled.			
Test Mode USER			
Disabled			
When the test mode user is activated, signals or measured data for PC and communication interfaces are labeled 'test mode'. In this situation all the output relays are blocked.			
Nominal Freq.			
50 Hz			
Setting for the nominal frequency of the protected system.			
Phase sequence			
A – B - C			
Setting the phase sequence A-B-C or A-C-B. (Alternative terminology: Setting for the rotary field's direction, either clockwise or anticlockwise.)			
Inom CT pri,a			
200	1	50000	A
Inom CT pri,b			
200	1	50000	A
Setting for the primary nominal current of the main current transformer (phase currents) of end a or b.			
Inom Y CT pri,a			
200	1	50000	A
Inom Y CT pri,b			
200	1	50000	A
Setting for the primary nominal current of the main current transformer at the neutral-point-to-ground connection.			
Inom device,a			
1.0 A			
Inom device,b			
1.0 A			
Setting for the nominal current of the device for the measurement of the phase currents of ends a or b. This also corresponds to the nominal device current.			
Inom Y device,a			
1.0 A			
Inom Y device,b			
1.0 A			
Setting for the nominal current of the device for the measurement of the neutral-point-to-ground currents of ends a or b. This also corresponds to the nominal device current.			

CT Ph. Dir, a
Standard
CT Ph. Dir, a
Standard
Instead of accounting for connection reversal applied to one end in the settings for **DIFF: Vec.gr. ends a-b PSx**, it is possible to account for it in the settings for connection of the measuring circuits. The connection of the phase current circuits, ends a and b, is set here as *Standard* if in accordance with the connection scheme shown in Chapter "Installation and Connection", else as *Opposite*.
CT Y Dir, a
Standard
CT Y Dir, b
Standard
If the connection is as shown in Chapter "Installation and Connection", then the setting must be *Standard*. If the connection direction is reversed then the setting must be *Opposite*.
Evaluation IN,a
Calculated
Evaluation IN,b
Calculated
There is two choice as Calculated or Measured. This setting specifies which current will be used by the HF6028 as the residual current: either the calculated residual current derived from the sum of the phase currents or the residual current measured at the fourth transformer.

Table 9.9 Differential Protection Setting

Parameter **Default**	**Min**	**Max**	**Unit**
General Enable			
No			
Disabling and enabling the differential protection function.			
Reference Power			
38.1	0.1	5000.0	MVA
Setting for the reference power, usually the nominal transformer power.			
Ref. current,a			
Not Measured	0.000	50.000	kA
Display of the reference current calculated by the HF6028 for end a.			
Ref. current,b			
Not Measured	0.000	50.000	kA
Display of the reference current calculated by the HF6028 for end b.			
Match fact.,a			
Not Measured	0.000	50.000	
Display of the matching factor calculated by the HF6028 for end a.			
Match fact.,b			
Not Measured	0.000	50000	
Display of the matching factor calculated by the HF6028 for end b.			

Table 9.10 REF_1 Ground Differential Protection Setting

Parameter / **Default**	**Min**	**Max**	**Unit**
General Enable			
No			
Disabling and enabling the REF_1 protection function.			
Meas. Input sel.			
End a			
Display of the measuring input for the values evaluated by the REF_1 protection function.			
Reference Power			
38.1	0.1	5000.0	MVA
Setting for the reference power, usually the nominal power for the relevant transformer end.			
Ref. current, Iref			
Not Measured	0.000	50.000	kA
Display of the reference current calculated by the HF6028.			
Match fact.,N			
Not Measured	0.000	50.000	
Display of the matching factor calculated by the HF6028.			
Match fact.,Y			
Not Measured	0.000	50000	
Display of the matching factor calculated by the HF6028 for the neutral-point current.			

Table 9.11 REF_2 Ground Differential Protection Setting

Parameter / **Default**	**Min**	**Max**	**Unit**
General Enable			
No			
Disabling and enabling the REF_2 protection function.			
Meas. Input sel.			
End b			
Display of the measuring input for the values evaluated by the REF_2 protection function.			
Reference Power			
38.1	0.1	5000.0	MVA
Setting for the reference power, usually the nominal power for the relevant transformer end.			
Ref. current, Iref			
Not Measured	0.000	50.000	kA
Display of the reference current calculated by the HF6028.			
Match fact.,N			
Not Measured	0.000	50.000	
Display of the matching factor calculated by the HF6028.			
Match fact.,Y			
Not Measured	0.000	50000	
Display of the matching factor calculated by the HF6028 for the neutral-point current.			

Table 9.12 DTOC1 Definite-Time Overcurrent Protection Setting

Parameter	Default	Min	Max	Unit
General Enable				
No				
Enabling/disabling the DTOC1 definite-time overcurrent protection function.				
Meas. Input sel.				
End a				
Selection of the measuring input that provides the measured values monitored by the definite-time overcurrent protection function.				

Table 9.13 DTOC2 Definite-Time Overcurrent Protection Setting

Parameter	Default	Min	Max	Unit
General Enable				
No				
Enabling/disabling the DTOC2 definite-time overcurrent protection function.				
Meas. Input sel.				
End b				
Selection of the measuring input that provides the measured values monitored by the definite-time overcurrent protection function.				

Table 9.14 IDMT1 Inverse-Time Overcurrent Protection Setting

Parameter	Default	Min	Max	Unit
General Enable				
No				
Disabling and enabling the IDMT1 inverse-time overcurrent protection function.				
Meas. Input sel.				
End a				
Selection of the measuring input that provides the measured variables monitored by the inverse-time overcurrent protection function.				

Table 9.15 IDMT2 Inverse-Time Overcurrent Protection Setting

Parameter	Default	Min	Max	Unit
General Enable				
No				
Disabling and enabling the IDMT2 inverse-time overcurrent protection function.				
Meas. Input sel.				
End b				
Selection of the measuring input that provides the measured variables monitored by the inverse-time overcurrent protection function.				

Table 9.16 THRM Thermal overload Protection Setting

Parameter **Default**	**Min**	**Max**	**Unit**	
General Enable				
No				
Disabling and enabling the THRM Thermal overload protection function.				
Meas. Input sel.				
End b				
Selection of the measuring input that provides the measured variables monitored by the Thermal overload protection function.				
Operating mode				
Relative Replica				
Setting for the operating mode of thermal overload protection. Select between Absolute replica and Relative replica.				

9.1.3.3 Protection Gx

Table 9.17 MAIN Function Setting

Parameter **Default**	**Min**	**Max**	**Unit**	
Vnom prim.,a PSx				
110.0	0.1	1500.0	kV	
Setting for the primary nominal voltage at end a of the transformer.				
Vnom prim.,b PSx				
110.0	0.1	1500.0	kV	
Setting for the primary nominal voltage at end b of the transformer.				
Phase reversal a PSx				
No swap				
Setting for the nominal frequency of the protected system.				
Phase reversal a PSx				
No swap				
Setting for the phase reversal function (see description for function group MAIN) for electrical machines in pumped storage power stations. Phases to be reversed (*A-B swapped*, *A-B swapped* or *A-B swapped*) may be set separately for each end.)				

Table 9.18 Differential Protection Setting

Parameter **Default**	**Min**	**Max**	**Unit**	
Enable PSx				
No				
This setting defines the Protection Gx (setting group) in which differential protection is enabled.				
Vec.gr. ends a-b				
0	0	11		

For standard connection of the HF6028, the vector group ID needs to be entered. For connection reversal applied to one individual end, this can be taken into account in setting (**CT Ph. Dir.,a** or **CT Ph. Dir.,b**). The following algorithms apply: Setting = ID + 6 If the addition results in a value > 12 then: Setting = (ID + 6) – 12 If the phase currents of the low and high voltage sides are exchanged and if this is not accounted for by the settings at **CT Ph. Dir.,a,z** (where z is end a,b) and **CT Ph. Dir.,z** (where z is end a,b) then the algorithm is: Setting = 12 – ID If an A-C-B phase sequence (or "anti-clockwise rotating field") is present then this should be entered as a setting at the HF6028. In this case, the HF6028 will automatically form the complementary value of the set vector group ID to 12: (vector group ID = 12 – set ID). For application of the HF6028 as machine protection, the setting must be 0 or 6 depending on the current transformer connection.				
Idiff> PSx				
0.2	0.1	2.5	Iref	
Operate value of the differential protection function as referred to the reference current of the relevant transformer end.				
Idiff>> PSx				
15.0	2.5	30.0	Iref	
Threshold value of the differential current for deactivation of the inrush stabilization function (harmonic restraint) and of the overfluxing restraint. **Note:** If the threshold is set too high, it is possible for the HF6028 not to trip in the presence of internal faults with transformer saturation.				
Idiff>>> PSx				
30.0	2.5	30.0	Iref	
This setting defines the threshold value for the differential current where the differential protection is triggered regardless of restraining quantity, inrush stabilization and saturation discriminator. **Note:** If the threshold is set too low, the HF6028 can trip in the presence of external faults with transformer saturation.				
m1 PSx				
0.3	0.1	1.5		
Gradient of the differential protection tripping characteristic for the range 0.5·Idiff> < IR ≤ IR,m1.				
m2 PSx				
0.7	0.1	1.5		
Gradient of the differential protection tripping characteristic for the range IR > IR,m2.				
IR,m2 PSx				
4.0	1.5	10.0	Iref	
Knee point where the tripping characteristic continues with the setting for gradient m2.				
Op.mode rush rst PSx				
Not phase selective				
Setting for the operating mode of the inrush stabilization function. For application of the HF6028 as machine protection, harmonic restraint can be disabled by way of this setting. For application of the HF6028 as transformer protection, the user can select				

whether the harmonic restraint should operate in cross-blocking mode or selectively for one measuring system.				
RushI(2f0)/ I(f0) PSx				
20 10 50 %				
Operate value of the inrush stabilization (harmonic restraint) of differential protection as a ratio of the second harmonic with the fundamental component of the differential current, in percent.				
0-seq. filt.a en. PSx				
Yes				
Enabling or disabling the zero-sequence filtering of winding a.				
0-seq. filt.b en. PSx				
Yes				
Enabling or disabling the zero-sequence filtering of winding b.				
Overflux.bl. en. PSx				
Yes				
Enabling or disabling the overfluxing restraint.				
Ov. I(5f0)/I(f0) PSx				
20 10 80 %				
Operate value of the overfluxing restraint of differential protection as ratio of the fifth harmonic component to the fundamental wave for the differential current, in percent.				
Op.del, trip sig. PSx				
0.00 0.00 100.00 s				
The time-delay of the differential protection trip signal can be set here.				

Table 9.19 REF_1 Ground Differential Protection Setting

Parameter **Default Min Max Unit**				
Enable PSx				
No				
This setting defines the Protection Gx (setting group) in which REF_1 Ground differential protection is enabled.				
Operating mode PSx				
Sum (Ip)				
Two operating modes can be selected. These modes are *sum(IP)* and *IP,max*.				
Bl.f.Diff trigg.				
No				
This setting determines whether the ground-differential short circuit protection is blocked in case of a starting of the differential protection.				
Idiff> PSx				
0.2 0.1 1.0 Iref				
Operate value of the ground differential protection function as referred to the reference current of the relevant transformer end.				
Idiff>>> PSx				
10.0 2.5 30.0 Iref				

Threshold value of the differential current for tripping by the ground differential protection function independently of the restraining variable.			
m1 PSx			
0.2	0.00	1.00	
Gradient of the differential protection tripping characteristic for the range IR < IR,m1 with the operating mode *IP,max.*			
m2 PSx			
1.5	0.15	1.5	
Gradient of the differential protection tripping characteristic for the range IR > IR,m2 with the operating modes *IP,max* .			
IR,m2 PSx			
1.0	0.1	1.5	Iref
Knee point from which the characteristic runs with a set gradient of m2 in operating mode *IP,max*.			

Table 9.20 REF_2 Ground Differential Protection Setting

Parameter **Default**	**Min**	**Max**	**Unit**
Enable PSx			
No			
This setting defines the Protection Gx (setting group) in which REF_2 Ground differential protection is enabled.			
Operating mode PSx			
Sum (Ip)			
Two operating modes can be selected. These modes are *sum(IP)* and *IP,max*.			
Bl.f.Diff trigg.			
No			
This setting determines whether the ground-differential short circuit protection is blocked in case of a starting of the differential protection.			
Idiff> PSx			
0.2	0.1	1.0	Iref
Operate value of the ground differential protection function as referred to the reference current of the relevant transformer end.			
Idiff>>> PSx			
10.0	2.5	30.0	Iref
Threshold value of the differential current for tripping by the ground differential protection function independently of the restraining variable.			
m1 PSx			
0.2	0.00	1.00	
Gradient of the differential protection tripping characteristic for the range IR < IR,m1 with the operating mode *IP,max.*			
m2 PSx			
1.5	0.15	1.5	
Gradient of the differential protection tripping characteristic for the range IR > IR,m2 with the operating modes *IP,max* .			

IR,m2 PSx			
1.0	0.1	1.5	Iref
Knee point from which the characteristic runs with a set gradient of m2 in operating mode *IP,max*.			

Table 9.21 DTOC1 Definite-Time Overcurrent Protection Setting

Parameter **Default**	**Min**	**Max**	**Unit**
Enable PSx			
No			
This setting defines the Protection Gx (setting group) in which DTOC1 definite-time overcurrent protection is enabled.			
tGS PSx			
0.00	0.00	100.00	s
Setting for the operate delay of the general starting signal of DTOC protection.			
Rush restr.enabl. PSx			
No			
Setting as to whether the inrush stabilization function (harmonic restraint) of differential protection shall be able to block the definite-time overcurrent protection function.			
I> PSx			
1.0	0.1	30.0	Inom
Setting for operate value I>.			
I>> PSx			
4.0	0.1	30.0	Inom
Setting for operate value I>>.			
I>>> PSx			
Blocked	0.1	30.0	Inom
1.00	0.00	100.00	s
Setting for operate delay I>.			
tI>> PSx			
0.50	0.00	100.00	s
Setting for operate delay I>>.			
tI>>> PSx			
0.50	0.00	100.00	s
Setting for the operate delay of the I>>> stage.			
Gen.starting mod PSx			
With strt IN/neg			
This setting defines whether starting of the residual current stages will result in the formation of the general starting signal of DTOC protection.			
Ineg> PSx			
0.25	0.1	8.0	Inom
Setting for operate value Ineg>.			
Ineg>> PSx			

Blocked	0.1	8.0	Inom
Setting for operate value Ineg>>.			
Ineg>>> PSx			
Blocked	0.1	8.0	Inom
Setting for operate value Ineg>>>.			
tIneg> PSx			
1.00	0.00	100.00	s
Setting for operate delay Ineg>.			
tIneg>> PSx			
0.50	0.00	100.00	s
Setting for operate delay Ineg>>.			
tIneg>>> PSx			
0.50	0.00	100.00	s
Setting for the operate delay of the Ineg>>> stage.			
Block tim.st.IN			
Without			
This setting defines whether blocking of the residual current stages will take place for single-pole or multi-pole phase current starting.			
IN> PSx			
0.25	0.1	8.0	Inom
Setting for operate value Ineg>.			
IN>> PSx			
Blocked	0.1	8.0	Inom
Setting for operate value IN>>.			
IN>>> PSx			
Blocked	0.1	8.0	Inom
Setting for operate value IN>>>.			
tIN> PSx			
1.00	0.00	100.00	s
Setting for operate delay IN>.			
tIN>> PSx			
0.50	0.00	100.00	s
Setting for operate delay IN>>.			
tIN>>> PSx			
0.50	0.00	100.00	s
Setting for the operate delay of the IN>>> stage.			

Table 9.22 DTOC2 Definite-Time Overcurrent Protection Setting

Parameter			
Default	**Min**	**Max**	**Unit**
Enable PSx			
No			
This setting defines the Protection Gx (setting group) in which DTOC2 definite-time overcurrent protection is enabled.			

tGS PSx			
0.00	0.00	100.00	s
Setting for the operate delay of the general starting signal of DTOC protection.			
Rush restr.enabl. PSx			
No			
Setting as to whether the inrush stabilization function (harmonic restraint) of differential protection shall be able to block the definite-time overcurrent protection function.			
I> PSx			
1.0	0.1	30.0	Inom
Setting for operate value I>.			
I>> PSx			
4.0	0.1	30.0	Inom
Setting for operate value I>>.			
I>>> PSx			
Blocked	0.1	30.0	Inom
Setting for operate value I>>>.			
tI> PSx			
1.00	0.00	100.00	s
Setting for operate delay I>.			
tI>> PSx			
0.50	0.00	100.00	s
Setting for operate delay I>>.			
tI>>> PSx			
0.50	0.00	100.00	s
Setting for the operate delay of the I>>> stage.			
Gen.starting mod PSx			
With strt IN/neg			
This setting defines whether starting of the residual current stages will result in the formation of the general starting signal of DTOC protection.			
Ineg> PSx			
0.25	0.1	8.0	Inom
Setting for operate value Ineg>.			
Ineg>> PSx			
Blocked	0.1	8.0	Inom
Setting for operate value Ineg>>.			
Ineg>>> PSx			
Blocked	0.1	8.0	Inom
Setting for operate value Ineg>>>.			
tIneg> PSx			
1.00	0.00	100.00	s
Setting for operate delay Ineg>.			
tIneg>> PSx			
0.50	0.00	100.00	s
Setting for operate delay Ineg>>.			
tIneg>>> PSx			

0.50	0.00	100.00	s
Setting for the operate delay of the Ineg>>> stage.			
Block tim.st.IN			
Without			
This setting defines whether blocking of the residual current stages will take place for single-pole or multi-pole phase current starting.			
IN> PSx			
0.25	0.1	8.0	Inom
Setting for operate value Ineg>.			
IN>> PSx			
Blocked	0.1	8.0	Inom
Setting for operate value IN>>.			
IN>>> PSx			
Blocked	0.1	8.0	Inom
Setting for operate value IN>>>.			
tIN> PSx			
1.00	0.00	100.00	s
Setting for operate delay IN>.			
tIN>> PSx			
0.50	0.00	100.00	s
Setting for operate delay IN>>.			
tIN>>> PSx			
0.50	0.00	100.00	s
Setting for the operate delay of the IN>>> stage.			

Table 9.23 IDMT1 Inverse-Time Overcurrent Protection Setting

Parameter **Default**	**Min**	**Max**	**Unit**
Enable PSx			
No			
This setting defines the Protection Gx (setting group) in which IDMT1 inverse-time overcurrent protection is enabled.			
tGS PSx			
0.00	0.00	100.00	s
Setting for the operate delay of the general starting signal of IDMT protection.			
Rush restr.enabl. PSx			
No			
Setting as to whether the inrush restraint of differential protection shall be able to block the inverse-time overcurrent protection function.			
Iref,P> PSx			
1.0	0.1	4.0	Inom
Setting for the reference current (phase current system).			
Charactristic P PSx			
Definite Time			
Setting for the tripping characteristic (phase current system).			

Factor kt,P
1.00 0.05 10.0
Setting for the factor kt,P of the starting characteristic (phase current system).
Min. trip t. P
1.00 0.00 10.00 s
Setting for the minimum trip time (phase current system).
Hold time P
0.00 0.00 600.00 s
Setting for the hold time for storing the starting time once the starting has dropped out (phase current system).
Release P
Without delay
Setting for the reset characteristic (phase current system).
Gen.starting mod PSx
With strt IN/neg
This setting defines whether starting of the residual current stages will result in the formation of the general starting signal of IDMT protection.
Iref,neg> PSx
Blocked 0.01 0.80 Inom
Setting for the reference current (negative-sequence current system).
Charactristic neg PSx
Definite Time
Setting for the tripping characteristic (negative-sequence current system).
Factor kt, neg
1.00 0.05 10.0
Setting for the factor kt,neg of the starting characteristic (negative-sequence current system).
Min. trip t. neg
1.00 0.00 10.00 s
Setting for the minimum trip time (negative-sequence current system).
Hold time neg
0.00 0.00 600.00 s
Setting for the hold time for storing the starting time once the starting has dropped out (negative-sequence current system).
Release neg
Without delay
Setting for the reset characteristic (negative-sequence current system).
Block tim.st.IN
Without
This setting defines whether a blocking of the residual and negative-sequence current stages should take place for single-pole startings or multi-pole phase current startings.
Iref,N> PSx
Blocked 0.01 0.80 Inom
Setting for the reference current (residual current system).
Charactristic N PSx
Definite Time

Setting for the tripping characteristic (residual current system).			
Factor kt, N			
1.00	0.05	10.0	
Setting for the factor kt,N of the starting characteristic (residual current system).			
Min. trip t. N			
1.00	0.00	10.00	s
Setting for the minimum trip time (residual current system).			
Hold time N			
0.00	0.00	600.00	s
Setting for the hold time for storing the starting time once the starting has dropped out (residual sequence current system).			
Release N			
Without delay			
Setting for the reset characteristic (residual current system).			

Table 9.24 IDMT2 Inverse-Time Overcurrent Protection Setting

Parameter **Default**	**Min**	**Max**	**Unit**
Enable PSx			
No			
This setting defines the Protection Gx (setting group) in which IDMT2 inverse-time overcurrent protection is enabled.			
tGS PSx			
0.00	0.00	100.00	s
Setting for the operate delay of the general starting signal of IDMT protection.			
Rush restr.enabl. PSx			
No			
Setting as to whether the inrush restraint of differential protection shall be able to block the inverse-time overcurrent protection function.			
Iref,P> PSx			
1.0	0.1	4.0	Inom
Setting for the reference current (phase current system).			
Charactristic P PSx			
Definite Time			
Setting for the tripping characteristic (phase current system).			
Factor kt,P			
1.00	0.05	10.0	
Setting for the factor kt,P of the starting characteristic (phase current system).			
Min. trip t. P			
1.00	0.00	10.00	s
Setting for the minimum trip time (phase current system).			
Hold time P			
0.00	0.00	600.00	s
Setting for the hold time for storing the starting time once the starting has dropped out (phase current system).			

Release P			
Without delay			
Setting for the reset characteristic (phase current system).			
With strt IN/neg			
This setting defines whether starting of the residual current stages will result in the formation of the general starting signal of IDMT protection.			
Iref,neg> PSx			
Blocked	0.01	0.80	Inom
Setting for the reference current (negative-sequence current system).			
Charactristic neg PSx			
Definite Time			
Setting for the tripping characteristic (negative-sequence current system).			
Factor kt, neg			
1.00	0.05	10.0	
Setting for the factor kt,neg of the starting characteristic (negative-sequence current system).			
Min. trip t. neg			
1.00	0.00	10.00	s
Setting for the minimum trip time (negative-sequence current system).			
Hold time neg			
0.00	0.00	600.00	s
Setting for the hold time for storing the starting time once the starting has dropped out (negative-sequence current system).			
Release neg			
Without delay			
Setting for the reset characteristic (negative-sequence current system).			
Block tim.st.IN			
Without			
This setting defines whether a blocking of the residual and negative-sequence current stages should take place for single-pole startings or multi-pole phase current startings.			
Iref,N> PSx			
Blocked	0.01	0.80	Inom
Setting for the reference current (residual current system).			
Charactristic N PSx			
Definite Time			
Setting for the tripping characteristic (residual current system).			
Factor kt, N			
1.00	0.05	10.0	
Setting for the factor kt,N of the starting characteristic (residual current system).			
Min. trip t. N			
1.00	0.00	10.00	s
Setting for the minimum trip time (residual current system).			
Hold time N			
0.00	0.00	600.00	s

Setting for the hold time for storing the starting time once the starting has dropped out (residual sequence current system).
Release N
Without delay
Setting for the reset characteristic (residual current system).

Table 9.25 THRM Thermal overload Protection Setting

Parameter **Default**	**Min**	**Max**	**Unit**
Enable PSx			
No			
This setting defines the Protection Gx (setting group) in which THRM Thermal overload protection is enabled.			
I Teta>			
1.15	0.10	4.00	Inom
Setting for the reference current			
Tim. Cons. Heat			
30.0	1.0	200.0	min
Setting for the thermal time constants of the transformer with current flow			
Tim. Cons. Cool			
30.0	1.0	200.0	min
Setting for the thermal time constants of the protected object without current flow			
K			
1.00	1.00	1.50	
Factor associated to Thermal value.			
Teta Trip			
100 %	50 %	200 %	
Setting for the operate value of the trip stage. Note: If the operating mode has been set to Absolute Replica, the setting here will be automatically set to 100%.			
Teta Alarm Enable			
NO			
This setting defines the Teta Alarm is enabled.			
Teta Alarm			
95 %	50 %	200 %	
Setting for the operate value of the warning stage			

10 COMMISSIONING

10.1 Safety Instructions

DANGER!

Only qualified personnel, familiar with the “Warning” page at the beginning of this manual, may work on or operate this device.

DANGER!

When installing and connecting the device the warning notices at the beginning of Chapter “Installation and Connection” (Chapter 6) must be observed.

DANGER!

The device must be reliably grounded before auxiliary voltage is turned on. . The flush-mounted case must be grounded in the area of the rear sidepieces at the location provided. The cross-section of the ground conductor must conform to applicable national standards. A minimum cross section of 2.5 mm^2 (US: AWG12 or thicker) is required.

DANGER!

Before working on the device itself or in the space where the device is connected, always disconnect the device from the supply.

DANGER!

The secondary circuit of live system current transformers must not be opened!

If the secondary circuit of a live CT is opened, there is the danger that the resulting voltages will endanger personnel and damage the insulation.

DANGER!

The power supply must be turned off for at least 5 s before power supply module V is removed. Otherwise there is the danger of an electric shock.

DANGER!

When increased-safety machinery is located in a hazardous area the LAPCO HF6028 must always be installed outside of this hazardous area.

Warning!

The PC interface is not designed for permanent connection. Consequently, the female connector does not have the extra insulation from circuits connected to the system that is required per VDE 0106 Part 101. Therefore, when connecting the prescribed connecting cable be careful not to touch the socket contacts.

Warning!

Application of analog signals to the measuring inputs must be in compliance with the maximum permissible rating of the measuring inputs (see “Technical Data”, Chapter 2).

Warning!

When using the programmable logic (function group LOGIC), the user must carry out a functional type test to conform to the requirements of the relevant protection/control application. In particular, it is necessary to verify that the requirements for the implementation of logic linking (by setting) as well as the time performance during device startup, during operation and when there is a fault (device blocking) are fulfilled.

10.2 Commissioning Tests

10.2.1 Preparation

After the LAPCO HF6028 has been installed and connected as described in Chapter “Installation and Connection”, the commissioning procedure can begin. Before turning on the power supply voltage, the following items must be checked again:

- Is the device connected to the protective ground at the specified location?
- Does the nominal voltage of the battery agree with the nominal auxiliary voltage of the device?
- Are the current and voltage transformer connections, grounding, and phase sequences correct?
- After the wiring work is completed, check the system to make sure it is properly isolated. The conditions given in VDE 0100 must be satisfied.

Once all checks have been made, the power supply voltage may be turned on.

After voltage has been applied, the device starts up. During startup, various startup tests are carried out. The LED indicators for HEALTHY (LED 4) and OUT OF SERVICE (H2) will light up. After approximately 15 s, the LAPCO HF6028 is ready for operation. By default, during this time the “Initializing” message is displayed on the first line of the LCD before the device has started up.

Once the “Initializing of HF6028 is finished and values of the currents (default display) are shown on the LC display, all settings can be entered. The procedure for entering settings from the integrated local control panel is described in the last sections.

If either the PC interface or the communication interface will be used for setting the LAPCO HF6028 and reading out event records, then the following settings must first be made from the integrated local control panel:

1. *Parameters/DeviceID/Password*
2. *Parameters/DeviceID/Device Address*

For PC interface via SARA software at the connection step, the communication setting should be set as below:

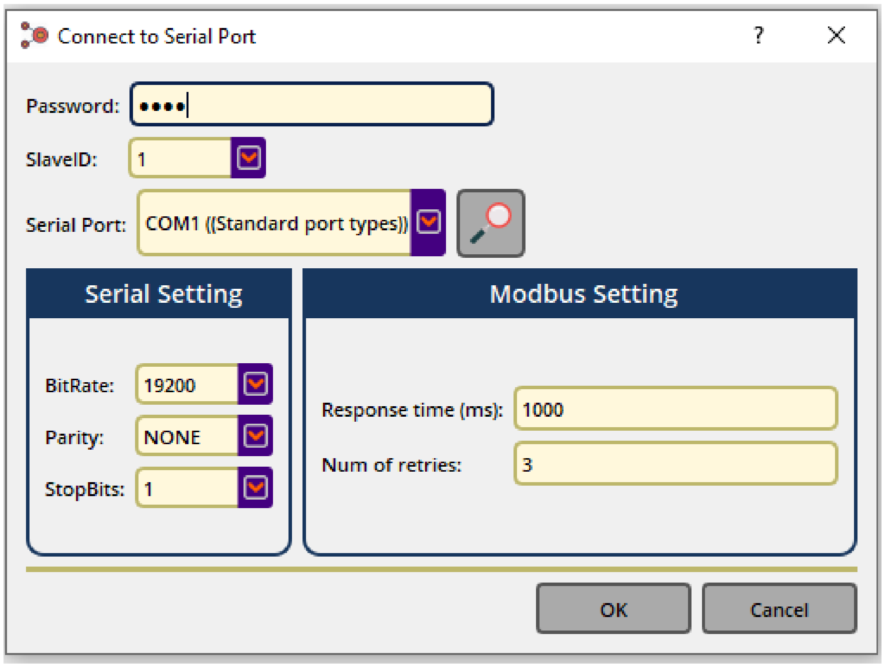


Fig. 10.1: connect to Serial Port in SARA Software

1. Password should be the same as HF6028 set password.
2. SlaveID should be the same as relay address (*Parameters/DeviceID/Device Address*).
3. Serial port: in these part, all the serial ports of the PC shown. The user must select the proper port which the connection cable is connected.
4. BitRate: the user should be noted that for LAPCO HF6028, the proper BitRate is "19200".
5. Parity: the user should be noted that for LAPCO HF6028, the correct Parity is "None".
6. StopBits: the user should be noted that for LAPCO HF6028, the correct StopBits is "None".

For more information, please refer to the help manual of SARA software. Instructions on these settings are given in Chapters "Settings".

After the settings have been made, the following checks should be carried out again before the blocking is cancelled:

- Does the function assignment of the binary signal inputs agree with the terminal connection diagram?
- Has the correct operating mode been selected for the binary signal inputs?
- Does the function assignment of the output relays agree with the terminal connection diagram?
- Has the correct operating mode been selected for the output relays?
- Have all settings been made correctly?

Now blocking can be cleared as follows (*Parameters/Function setting/General function* menu branch):

- Protection Enabled = *Yes (= on)*
- Test Mode USER = *Disabled*

10.2.2 Testing

By using the signals and displays generated by the LAPCO HF6028, it is possible to determine whether the HF6028 is correctly set and properly interconnected with the station. Signals are signaled by output relays and LED indicators and entered into the event memory. In addition, the signals can be checked by selecting the appropriate signal in the menu tree.

If the user does not wish the circuit breaker to operate during protection testing, the trip commands can be blocked through (*Parameters/Function setting/Genertal function* menu branch):

- *Test Mode USER = Contacts Blocked*

or an appropriately configured binary signal input as an trip cmd. Bl. X (in *Parameters/Config. setting/INPUTS* menu branch).

If circuit breaker testing is desired, it is possible to assign a setting such as “DIFF: Enabled” to the output relay (in *Parameters/Config. setting/OUTPUTS* menu branch). The user should be noted that the differential function must be enabled before this test is applied.

10.2.3 Checking the Binary Signal Inputs

By selecting the corresponding state signal (*Operation/Phy.state signal*), it is possible to determine whether the input signal that is present is recognized correctly by the device. The values should be displayed similar to the below example:

Inuts: 7654321
0010101

and have the following meanings: *"0"*: Not energized and *"1"*: Energized.

This display appears regardless of the binary signal input mode selected.

10.2.4 Checking the Output Relays

It is possible to trigger the output relays, by assigning a setting such as “DIFF: Enabled” to the output relay (in *Parameters/Config. setting/OUTPUTS* menu branch). The user should be noted that the differential function must be enabled before this test is applied. In this case, Using the Local control panel menu in the (*Operation/Phy.state signal*), it is possible to determine whether the output relay is energized or not. The values should be displayed similar to the below example:

Outputs: 87654321
00100101

and have the following meanings: ● *"0"*: Not energized and *"1"*: Energized.

Warning!

The user is advised to also check the performance of output relays form the rear terminal connection. The user is also advised to check the performance of the output relays from the rear terminal connection.

10.2.5 Checking the Protection Function

Four parameter subsets are stored in the HF6028, one of which is activated. Before checking the protective function, the user should determine which parameter subset is activated. The active parameter subset is displayed at PSS: param.sub.sel (*Parameters/Function setting/Global/PSS*):

10.2.6 Checking Differential Protection

For single-side feed, the fault current characteristic crosses the first knee of the tripping characteristic of the LAPCO HF6028 so that the basic threshold value is always checked.

The current I to which the LAPCO HF6028 responds for single-side feed is calculated as follows:

$$I = \frac{I_{diff>} . I_{nom,z}}{K_{am,z}}$$

- z: transformer end (a, b)
- $I_{diff>}$: set operate value
- $I_{nom,z}$: nominal current of the LAPCO HF6028 for transformer end a, b
- $k_{am,z}$: amplitude-matching factor of transformer end a, b

For single-side one-phase or two-phase feed, a vector group-matching factor in accordance with the set vector group ID needs to be taken into account in addition to the amplitude-matching factor. The vector group-matching factors are given in the tables 10.1 to 10.4 and the threshold current is calculated as follows:

$$I \geq \frac{I_{diff>} . I_{nom,z}}{K_{am,z} . K_{s,y,z}}$$

- z: transformer end (a, b)
- $I_{diff>}$: set operate value
- $I_{nom,z}$: nominal current of the LAPCO HF6028 for transformer end a, b
- $k_{am,z}$: amplitude-matching factor of transformer end a, b
- $k_{s,y,z}$: vector group-matching factor (see tables 10.1 to 10.4)

The differential and restraining currents formed by the LAPCO HF6028 are displayed as measured operating data (it can be seen by SARA software in the measurement part as I Diff, I Res). They aid in assessing whether the connection of the LAPCO HF6028 to the system current transformers and the setting of the vector group ID are correct. The tables 10.1 to 10.4 give the factors ks which serve to calculate the differential current for single-side feed.

In evaluating the test results, one should be aware that the HF6028 will trip as follows, if a value of $I_{diff>>}$ or $I_{diff>>>}$ is exceeded.

- $I_{diff>>}$ exceeded: Trip regardless of the inrush and overfluxing restraint;
- $I_{diff>>>}$ exceeded: Trip regardless of the restraining current and regardless of all other restraints.

Table 10.1 Factors for single-side, one-phase feed in phase A, zero sequence-filtered

Transformer end	a	b (when injection is from LV side)											
Vector group ID		0	1	2	3	4	5	6	7	8	9	10	11
IDiff1	0.666	0.666	0.577	0.333	0.000	0.333	0.577	0.666	0.577	0.333	0.000	0.333	0.577
IDiff2	0.333	0.333	0.00	0.333	0.577	0.666	0.577	0.333	0.000	0.333	0.577	0.666	0.577
IDiff3	0.333	0.333	0.577	0.666	0.577	0.333	0.000	0.333	0.577	0.666	0.577	0.333	0.000

Table 10.2 Factors for single-side, two-phase, phase-opposition feed in phases B to C, zero sequence filtered

Transformer end	a	b (when injection is from LV side)											
Vector group ID		0	1	2	3	4	5	6	7	8	9	10	11
IDiff1	0.000	0.000	0.577	1.000	1.154	1.000	0.577	0.000	0.577	1.000	1.154	1.000	0.577
IDiff2	1.000	1.000	1.154	1.000	0.577	0.000	0.577	1.000	1.154	1.000	0.577	0.000	0.577
IDiff3	1.000	1.000	0.577	0.000	0.577	1.000	1.154	1.000	0.577	0.000	0.577	1.000	1.154

Table 10.3 Factors for single-side, one-phase feed in phase A, not zero sequence-filtered

Transformer end	a	b (when injection is from LV side)					
Vector group ID		0 = 12	2	4	6	8	10
IDiff1	1.000	1.000	0.000	0.000	1.000	0.000	0.000
IDiff2	0.000	0.000	1.000	0.000	0.000	0.000	1.000
IDiff3	0.000	0.000	0.000	1.000	0.000	1.000	0.000

Table 10.4 Factors for single-side, two-phase, phase-opposition feed in phases B to C, not zero sequence-filtered

Transformer end	a	b (when injection is from LV side)					
Vector group ID		0 = 12	2	4	6	8	10
IDiff1	0.000	0.000	1.000	1.000	0.000	1.000	1.000
IDiff2	1.000	1.000	0.000	1.000	1.000	1.000	0.000
IDiff3	1.000	1.000	1.000	0.000	1.000	0.000	1.000

10.2.7 Checking REF_1 and REF_2 Ground Differential Protection

The current I to which the LAPCO HF6028 responds for single-side feed, directly into the **neutral-point side**, is calculated as follows:

$$I \geq \frac{I_{diff>} . I_{nom}}{K_{am,z}}$$

z: transformer end (a, b)

- $I_{diff>}$: set operate value
- I_{nom}: nominal current of the LAPCO HF6028
- $k_{am,z}$: amplitude-matching factor of transformer end a, b

There will be no trip for single-side, single-pole, phase-side feed.

The differential and restraining currents formed by the HF6028 are displayed. (It can be seen by SARA software in the measurement part as I Diff REF_1 or 2, I Res REF_1 or 2).

10.2.8 Completing Commissioning

Before the LAPCO HF6028 is released for operation, the user should make sure that the following steps have been taken:

- All memories have been reset. It is recommended to “Erase Disturbance Records” in Disturbance Records parts of SARA. Also “Erase Events” in event part of SARA software.
- Blocking of output relays has been cancelled.
- Blocking of the trip command has been cancelled.
- The device is on-line.

In the *Parameters/Function setting/General function* menu branch: (Protection Enabled, setting Yes (= on).)

After completion of commissioning, only the green LED indicator signaling “HEALTHY” (LED 4) should be on.

11 TROUBLESHOOTING

11.1 Problems

1. Lines of text are not displayed on the local control panel:

- Check to see whether there is supply voltage at the device connection points.
- Check to see whether the magnitude of the auxiliary voltage is correct.

The HF6028 is protected against damage resulting from polarity reversal.

2. The HF6028 issues a “Warning” signal on LED 3. In this case HF6028 is blocked.

- The below list shows possible warning indication:

a) The reference current determined by the HF6028 for differential protection is not within the permissible range.

b) The calculated amplitude matching factor of the differential protection function is above the permissible range.

c) The ratio of the amplitude matching factors for differential protection is not within the permissible range.

d) The highest amplitude matching factor for differential protection is smaller than permitted.

e) The lowest amplitude matching factor of the differential protection function is lower than permitted.

f) The reference current determined by the HF6028 for REF_1 or 2 ground differential protection is not within the permissible range.

g) The calculated amplitude matching factor of REF_1 or 2 ground differential protection function is above the permissible range.

h) The ratio of the amplitude matching factors of the differential protection function is not within the permissible range.

12 STORAGE

Devices must be stored in a dry and clean environment. A temperature range of -25°C to +70°C (-13°F to +158°F) must be maintained during storage. The relative humidity must be controlled so that neither condensation nor ice formation will result.

If the units are stored without being connected to auxiliary voltage, then the electrolytic capacitors in the power supply area need to be recharged every 4 years. Recharge the capacitors by connecting auxiliary voltage to the HF6028 for approximately 10 minutes.

If the units are stored during a longer time, the battery of the power supply module is used for the continuous buffering of the event data in the working memory of the processor module. Therefore, the battery is permanently required and discharges rapidly. In order to avoid this continuous discharge, it is recommended to remove the power supply module from the mounting rack during long storage periods. The contents of the event memory should be previously read out and stored separately!

13 ORDER INFORMATION

Order form

HF 6028

Ready-to-use configuration

Two Winding Transformer Diff. Prot. HF 6028	3	A	8	0	0	E	0	1
Basic device :								
Basic device 6 inch, ring and pin terminal connection	3							
Basic device 8 inch, ring and pin terminal connection	8							
basic complement 7 binary inputs, 8 output relays								
Mounting option and display :								
Flush mounted, enhanced local control panel with text display		A						
Surface mounted, enhanced local control panel with text display		B						
Flush mounted, with enhanced detachable HMI		E						
Surface mounted, with enhanced detachable HMI		F						
Processor extension and Current transformer :								
With DSP-Coprocessor, Inom = 1A/5A			8					
Inom = 1A/5A			9					
Voltage transformer :								
Without Voltage transformer				0				
Vnom = 50…130V (1 pole)				1				
Additional binary I/O options :								
Without					0			
With 1 binary module (add. 6 binary inputs and 8 output relays)					1			
With 1 binary module (add. 6 binary inputs and 6 output relays (2-pole))					5			
for the control of up to 3 switchgear units								
Power supply and additional binary I/O options:								
VA,nom = 24 … 60 VDC						D		
VA,nom = 90 ... 250 VDC / 90 ... 250 VAC						E		
Further add. Options :								
Without							0	
With analogue module							2	
With binary module (add. 24 binary inputs)							4	

Communication interface

MODBUS / MODBUS (RS485 /RS232)	**1**
KBUS / COURIER / MODBUS - not available 3)	**2**
IEC60870-5-103 / MODBUS (if 2nd RS485 available)	**3**
DNP3 / MODBUS (if 2nd RS485 available)	**4**
IEC60870-5-103 / IEC60870-5-103 (if 2nd RS485 available)	**5**
Modbus TCP/IP / Modbus (if 2nd RS485 available)	**6**
IEC60870-5-103 Eth / Modbus (if 2nd RS485 available)	**7**

SN : DIFYYWWNNNNN	DIF	Y	Y	W	W	N	N	N	N	N
Production Year										
Production Week										
Production Number										

14ATTACHMENT

Tavanir Company Protection Reference Relay Laboratory

Certificate

on Standard Type Tests Approval for LAPCO- HF6028

بسمه تعالی

شماره : ۲۷۵۰۰/۸۴۹۴
تاریخ : ۱۴۰۰/۰۹/۲۲

شرکت مدیریت تولید، توزیع و انتقال نیروی برق ایران

احراز حصول استانداردهای تولید موضوع بند ۳ بخش الف ماده ۷ آئین نامه اجرایی بندالف ماده ۲۶ قانون برگزاری مناقصات و با توجه به ماده ۲۷ آئین نامه اجرایی بند ج ماده ۱۲ قانون برگزاری مناقصات مبنی بر احراز حداقل استانداردهای الزامی

بدینوسیله مطابقت با استانداردهای تولید درارابطه با:

- **رله حفاظتی دیجیتال دیفرانسیل ترانس، مدل LAPCO-HF6208**

تولیدشده توسط **شرکت همیان فن** با توجه به مستندات زیرکه سوابق‌آن براساس نامه شماره ۲۷۵۰۰/۸۳۲۵ مورخ ۱٤۰۰/۹/۱۷ دردفتر تحقیقات و توسعه فناوری نگهداری می‌شود مورد تأیید می‌باشد.

۱- تأیید انجام آزمون‌های نوعی و طراحی مطابق با استاندارد **IEC 60255-1(2009)** که در آزمایشگاه‌های مرجع رله و حفاظت، سنجش کیفیت و سازگاری الکترومغناطیسی دانشگاه امیرکبیر انجام پذیرفته و در سیصد و چهل هفتمین جلسه شورای ارزیابی و مطابقت با استانداردهای تولید مورد بررسی و به تأیید رسیده است.

۲- تأیید وجود تجهیزات آزمون‌های جاری ساخت و دارا بودن برنامه کنترل کیفیت که طی نامه فوق‌الذکر به تأیید رسیده است.

لازم به توضیح است که گواهی حاضر به استناد موافقت مدیریت محترم عامل شرکت توانیر در هامش نامه شماره ۲۷۲۰۰/۱۰۹۵ مورخ ۸۶/۵/۲۱ (نحوه ارائه گواهی مطابقت با استانداردهای تولید) صادر شده است. ضمناً این گواهی صرفاً در رابطه با بند ۳ بخش الف ماده ۷ آئین نامه اجرایی بند الف ماده ۲۶ قانون برگزاری مناقصات و با توجه به فصل چهارم آئین نامه ارزیابی کیفی مناقصه گران جهت ارائه به کمیته فنی - بازرگانی در دستگاه مرکزی مسئول تشخیص صلاحیت صادر شده و اعتبار دیگری ندارد.

شرکت تولیدکننده مجاز به تغییر در طراحی محصول و یا قطعات منفصله و یا کیفیت مواد اولیه که این گواهی برای آن صادر شده نمی‌باشد و درصورت هر نوع تغییری گواهی فوق فاقد اعتبار می‌باشد و تولیدکننده باید مراحل صدور گواهی مطابقت با استانداردهای تولید را برای کالای تغییر یافته که محصول جدید محسوب می‌شود طی نماید. مسئولیت خسارت‌های احتمالی ناشی از موارد فوق‌الذکر و ارائه کالای تغییریافته بدون اطلاع‌رسانی و دریافت گواهی جدید بر عهده شرکت تأمین‌کننده کالا خواهد بود. همچنین درصورتیکه مطابق استانداردهای ملی، بین‌المللی و یا الزامات وزارت‌نیرو انجام آزمون‌های جدید (سخت‌افزاری، نرم‌افزاری) الزامی گردد تولیدکننده موظف خواهد بود ظرف مدت تعیین شده توسط شرکت توانیر نسبت به انجام آزمون‌های جدید اقدام نماید در غیر این صورت گواهی حاضر فاقد اعتبار خواهد بود، استفاده از این گواهینامه در چارچوب قوانین و مقررات دولت جمهوری اسلامی ایران مجاز است.

اعتبار این گواهی از تاریخ صدور به مدت دو سال است.

سید حسین سجادی
رئیس کمیته فنی بازرگانی شرکت توانیر