Digital Motor, Overload and Overcurrent-Time Protection DM 2

1 Application

This multifunction protection device is used for

- thermal protection of three-phase a.c. motors, preferably of high voltage motors,
- overload and short circuit protection for transformers and lines, so a two-stage overcurrent-time protection and the thermal replica can be combined,
- earth current supervision using a separate current transformer.

Because the starting operation monitoring and blocked rotor monitoring may be switched off in favour of a complete overcurrent-time protective function, the DM 2 can be applied in all system types as definite-time overcurrent protection too.

2 Main characteristics

- Due to its compact design it can also be mounted into low-depth switchgear cells.
- Selection of rated current (1 or 5 A) is easy by terminal connection.
- A short start-up time of the protection device ensures quickest availability after auxiliary voltage was not applied.
- Readout and setting are menu driven so the use of the PC operator software is not forced.
- Identical philosophy of both operating with the device and with PC operating program ensures to find one's way quick.
- The use of binary "functional switches" for setting the device enables a simple selection between functional alternatives. The winning advantage of this adjustment method is the automatic suppression of all settings, which are not necessary. This decreases the size of adjustment.
- All inputs and outputs can be freely assigned in a matrix with rows containing software-functions and columns representing physical I/O's.
- Logic combination for inputs is possible (optocoupler inputs).
- The setting sets are stored in an EEPROM so as to be preserved if the supply voltage and the back-up battery fail.
- For instant enlightenment of both system and protection device status one can use LED indications, measurand display and short reports on LCD.
- In addition to the event logging a disturbance recorder is integrated which ensures diagnostic and documentation of operation and fault events.
- Two switchable characteristic sets allow adaptation to changed conditions instantly.
- Thermal replica is based on current r.m.s values.
- Heavy startings can be supervised.
- Measures to increase the reliability and availability include - among other things - a comprehensive program of self-diagnostic functions as well as invokable tests.

3 Design

The DM 2 is housed in a sheet-steel enclosure in the following designs:

- panel surface-mounting
- panel flush-mounting.

Additionally three different installation positions exist – current terminals

- at the bottom
- right or
- left hand side

For both versions, the low depth of 140 mm allows the installation into medium-voltage switchgear cells. So behind the DM 2 other devices like terminals may be located.

For panel surface mounting, the terminals can be accessed from the front panel, whereas for panel flush-mounted units they can be accessed from the rear side.

The front operator panels of both versions are equal. They include the membrane keyboard, a four-line LCD display of 20 characters per line, 12 LED's and a 9-pin Sub-D connector for plugging in a PC.

The optional IEC 60870-5-103 interface is available in two physical designs: optical fibre connection or RS485 twisted pair wire. All are located in the upper level of the terminals. The alternative RS485 wire interface uses terminals.

4 Protective functions

4.1 Thermal replica

The thermal replica operates with "memory", i.e. in regard of the preloading according to IEC 60255-8.

The time response for the trip results in:

$$t_a = \tau \cdot \ln \left[\frac{\left(\frac{I}{I_B}\right)^2 - \left(\frac{I_p}{I_B}\right)^2}{\left(\frac{I}{I_B}\right)^2 - k^2} \right]$$

wherein are:

t_a: tripping time after overload has been started

τ: heating time constant of equipment

I: actually flowing current

I_B: basic current (nominal current of the protective object)

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I_p: preloading current
k: factor for multiplying the basic current to reach the operating limit

The tripping is issued at the thermal level of 100%. This level will be reached by definitions, when at an ambient temperature of 20 °C the current $I = k \cdot I_B$ is flowing.

Previous to a thermal trip, warning signals on adjustable percentage levels of the thermal replica can be passed. For this, two warning levels are provided.

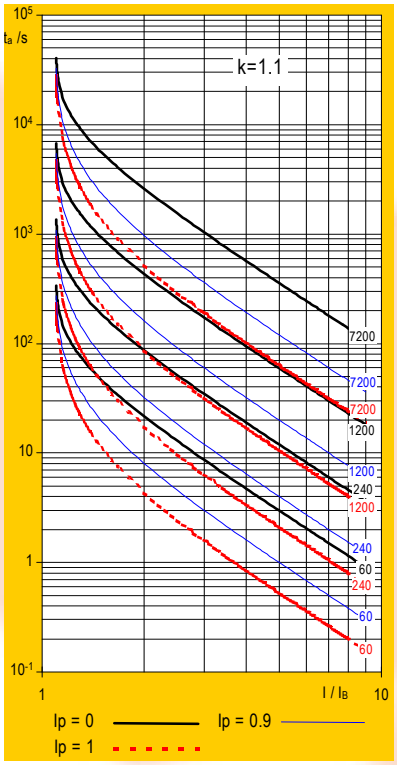

Fig. 1: tripping time characteristics for several heating time constants τ and preloading currents I_P at k = 1.1

Adapting to variously equipment and observing additional standards, three different thermal characteristics may be selected:

1. Single characteristic with equal heating and cooling thermal time constant - preferably for overload protection of transformers, cables, etc.
2. Single characteristic with a different thermal time constant at zero current ($I<I_{min}$) for motor protection.
3. Heating characteristic consists of two parts. The first part is effective with adjusted heating time constant up to $1.3 \cdot I_B$. From $I>1.3 \cdot I_B$ the heating time constant τ = 600 s is applied. At $I = 1.5 \cdot I_B$ the tripping is guaranteed with 120 s. In the whole area the cooling comes with the adjusted time constant respectively at $I < I_{min}$ with the corresponding multiple analogue to item 2. for motor protection.

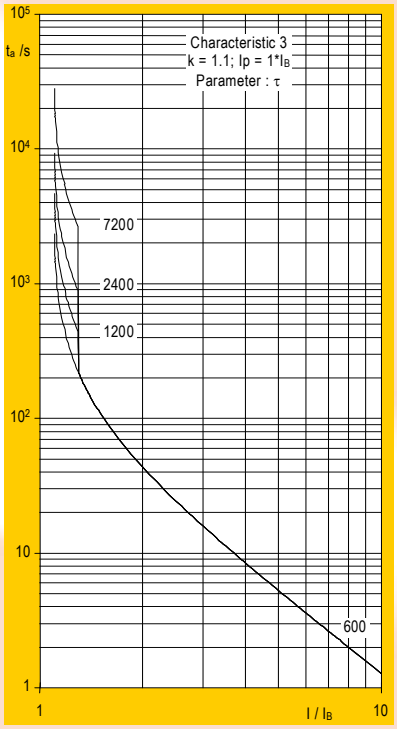

Fig. 2: characteristic type 3

4.2 Starting operation and rotor blocking monitoring (for motor protection)

The protector recognises the motor starting by the current step change from I < Imin to I_{st} < I < I». Every starting operation will be monitored by a separate starting temperature storage.

When the starting operation exceeds the value for the starting level adjustable by the starting-time, there will be a trip command.

The starting operation counter enables the quantity of motor startings specified as input value. When the first starting is a hot start, the admissible number is reduced by one.

The state "rotor is blocked" of the protector leads to the trip command, when this state takes longer as an adjustable time.

When a tacho switch is connected, signalling zero or low speed, a blocked rotor can be recognised even during a starting operation.

4.3 Reclosing lockout

The reclosing lockout prevents the switching on of the protective object. It will be set:

- after a trip by the thermal replica,
- at exceeding the admissible maximum number of motor startings,
- selectively also at reaching a warning level of the thermal replica or reaching a winding,
- optional after tripping by overcurrent-time protection.

Reclosing lockout is released by falling below its settable limiting values or by an input signal.

4.4 Asymmetry and phase failure

The three phase currents are monitored regarding to asymmetry and with this also to phase failure. The state "current asymmetry" has to be applied for an adjustable time until the trip command is issued.

4.5 Underload protection

For the underload protection the current will be monitored. When Imin < I < I_U is longer than a defined time, the underload protection is tripping. I_U is the threshold value of the underload current to be entered.

4.6 Definite-time phase-selective overcurrent protection $I_L>$, $t_{IL>}$, $I_L>>$, $t_{IL>>}$

Besides the thermal replica, the motor starting and blocked rotor monitoring at the motor protection, the short-circuit protection operating with up to two set values can be used.

In each phase the current will be measured. Overranging the operate value $I_L>$ or $I_L>>$, a trip command will be given delayed for the time $t_{IL>}$ or $t_{IL>>}$. The resetting ratio for the $I_L>>$ starting is adjustable.

4.7 Earth-fault current-time protection

The earth-fault current definite-time protection is two-stepped, overcurrent ($I_E>$) and high current ($I_E>>$).

The earth-fault current is detected by a fourth transformer or calculated.

To avoid spurious starts of the earth-fault current-time protection, for example due to transformer errors, the operate value is stabilised. Stabilising the earth-fault current is serving to raise the operate value of the $I_E>$ stage depending on the total of all phase currents (see Fig. 3).

It is effective only after exceeding the adjustable current amount I_{stab}.

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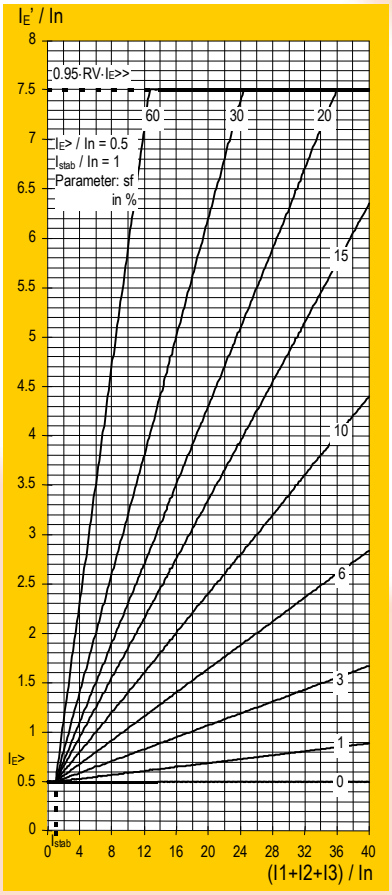

Fig. 3: Characteristic of earth-fault current stabilisation $I_E' = g (sf, \Sigma I_L)$

4.8 Processing of input signals

This stage permits the logic operation of the optocoupler input signals among each other. The functions AND, OR are available. A negation (NOT) of the signals is possible.

4.9 Change of characteristic sets

Two characteristic sets may be entered. The respectively active set can be selected by an operator action or by command from the substation control system. Changing the configuration allows to switch between the characteristic sets using the optocouplers.

5 Additional functions

5.1 Display of operating values

As long as no trip, alarm or malfunction messages are present, the DM 2 display indicates

- by turns the measured operate currents respectively the thermal level.
- Instead of currents and thermal level, the level of the motor starting storage is displayed at start-ups.
- With currents the user may chose between primary or secondary amounts.

5.2 Visual display of system faults

For a first short information concerning a system fault or device status, 12 light emitting diodes (LED's) and a four-line display with 20 characters each per line are available.

LED	steady light		flashing light	
green G	protection available	u	–	
red R	alarm	l t	malfunction	l t
yellow 0	TRIP thermal	l t	–	
yellow 1	TRIP starting	l t	TRIP blocking	l t
yellow 2	–		TRIP I_L>>	l t
yellow 3	TRIP I_E>	l t	TRIP I_E>>	l t
yellow 4	TRIP underload	l t	TRIP asymmetry	l t
yellow 5	warning 1 thermal	u	warning 2 thermal	u
yellow 6	starting	u	blocking	u
yellow 7	underload	u	reclosing lockout	u
yellow 8	asymmetry	u	I_L>>	u
yellow 9	I_E>	u	I_E>>	u

Table 1: LED assignment on delivery for DM 2 (abbreviations are as follows:
u: updating l: latching
t: additional indication on LCD)

The LED display may be shown either in steady light or flashing light, while the flashing light dominates.

The LED display as delivered in the standard configuration is shown in Table 1. As an output command can be derived practically from each subfunction of the DM 2, the LED assignment can be changed within wide limits by changing the configuration.
The four-line LCD text display shown after a TRIP command includes the tripping reason.
More detailed information can be found in the event and disturbance data memories of the relay.

5.3 Event logging

Events are stored time-stamped and numbered for analysing the incidents and protector's actions. Event logging is used to make a follow-up analysis of what happened in the protective object and in the protective relays.
To achieve a better survey, the events are divided into the following groups:

- system faults,
- indications,
- operator actions and
- internal malfunctions and alarms.

Moreover, it can be seen whether the events occurred during

- normal, or
- test operation.

The division into

- main and
- subevents

supports the temporal classification.
Main events are numbered and time-stamped. Subevents contain the time in ms relative to the assigned main event.

The content of the event memory can be selected and displayed on the front panel without using a PC.
The installed back-up battery preserves the event memory content even if the supply voltage fails.

5.4 Disturbance data logging

Disturbance data logging means the storage of the digitised instantaneous values of measured input quantities together with the time marks of some important events (like start, trip and optocoupler inputs). Logging clock is 1 ms. Logging is activated by:

- system faults located by the protector or
- external logging signals

For logging the power system failures, there are two possibilities:

1. Continuous logging from "coming" to "going" of the general start with a 50ms pre-travel, where the maximum logging duration for a fault is 4 s,
2. event controlled logging with 50 ms pre-travel and 150 ms overtravel.
   The controlling events are:
   - starting comes,
   - starting goes,
   - starting changes,
   - TRIP-command

Several logs with a total of ca. 19 s are possible. The disturbance data logging caused by an input signal is always continuous during the active signal, max. 4 s.
The stored disturbance data can only be visualised on a PC screen using PC operating programs.
The installed back-up battery preserves the content of the disturbance data memory if the supply voltage fails.

5.5 Time synchronisation

Beside the default time synchronisation by a substation control system it is possible to set the time 12:00:00 by an optocoupler input signal.

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6 Test functions

6.1 Automatic self-tests

Comprehensive monitoring routines of the hardware and for the software are provided to detect and signal malfunctions of the protector. After the tests during start-up there are running cyclic tests.
Depending on the detected abnormal condition, the protector is taken out of operation or an alarm is issued. Using the green LED to indicate the ready state (in service) and the red LED for malfunction and alarm signal is advisable. The pre-configured signal relay “Protection available“ signals any malfunction and lack of auxiliary voltage. Alarms may be configured to another signal relay.

When functional key “Tests” is pushed manual hardware tests are available:

6.2 C.B.-Test

To test the tripping circuits of the circuit breaker, a trip test may be performed.

6.3 Optocoupler Test

In the “Tests” menu optocoupler test can be selected. The actual state of all inputs is shown.

6.4 Test of fibre optic interfaces

An easy to use check for transmitter, receiver and fibre optic cable is integrated.

6.5 Application of test plug devices

Checking the mounted protection relays periodically many power supply companies apply test plug devices or test selector switches that cause a safe switch over from the measured quantities of the system to the test devices. The TRIP command to the circuit breaker is also involved into the switch over.
When the "test mode" is established, the test plug device or the test selector switch must provide a binary signal for one optocoupler input of DM 2 relay.
This marks all logged events as “test“. Information blocking is available to substation control equipment by an optocoupler input too.

7 Serial interfaces

The front 9-pole Sub-D connector constitutes the interface S0 for the operator PC.

The IEC 60870-5-103 interface S1 for connection to the substation control system is available as an option. The optical fibre variant is a point-to-point connection while the RS485 is a twisted-pair half-duplex connection (several devices may be connected).

8 Operation

8.1 Front panel

The following operations can be executed on the front panel:

- Reading and resetting of LED’s and display provided automatically by the relay including the following:
  - operating value display during normal operation,
  - LCD report after a TRIP command of the protector,
  - LCD report after switching off the protector and also as a result of an internal malfunction.
  - In case of an alarm, the operating values and the alarms are displayed.
- Setting of the protector
  Pressing the password-protected "Setting" key displays an easily comprehensible plain-text menu comprising the following main items:
  - *Equipment adaptation* - data concerning the installation and the system,
  - *Protective functions* -- switching the protective and additional functions on or off,
  - *Input configuration* - free assignment and logic combination of optocoupler input signals to device software functions.
  - *Output configuration of relays and LED's* - free assignment of the possible output commands to trip relays, signal relays and LED's, this can generate group signals,
  - *Characteristic sets* - setting values for the selected protective functions are separately adjustable for two characteristic sets,
  - *Device address,*
  - *Operator control* - common settings, e.g. protector On/Off, password, date and time, operating mode, etc.
- Display of stored information
  After pressing the "Readout" key the stored information may be indicated on the display:
  - logged events (with running time),
  - all settings,
  - information on the protector type, e.g. versions.

  As the key is not password-protected and the information selection is shown in a plain-text menu, it is easy to get a local readout.
- Calling of tests
  Pressing the "Tests“ key accesses a menu used for the above-mentioned tests and the manufacturer's service. The menu is password-protected.

8.2 PC operator routine COMM-3

Although no PC software is necessary for setting and readout of the protection device a PC operator routine COMM-3 and graphic software SDA 2 is available. It is used for preparing and performing the setting of the digital protection relay at the engineer's place of work. In addition to setting the protectors, the routine may also be used for reading out and displaying events and with the additionally graphics software SDA 2 disturbance data can be displayed. Archiving of settings and events is easy to do.
Graphic display and evaluation of disturbance data are by the graphics software featuring the COMTRADE file format (IEEE standard C37.1991). Using this file format data exchange may be performed between compatible devices such as state of the art test devices.

8.3 Control by substation

The IEC 60870-5-103 interface of digital protectors to the substation control equipment is optionally available. Regardless of the manufacturer, this interface supports the connection of protectors to correspondingly compatible equipment.
The agreed scope of signals, disturbance data and commands for an overcurrent-time protection is available; the compatibility class is 2.

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9 Specifications

The protection relay satisfies the requirements of the product standards EN 60255-6 (IEC 60255-6); DIN 57435, part 303; IEC 60255-8.

Mechanical construction

- sheet-steel housing for panel surface mounting
  or panel flush mounting
- dimensions see dimensioned drawings
- weight approx. 5.5 kg
- degree of protection: housing IP 51
  terminals IP 20
- terminals
  transformers solid wire 0.5 ... 16 mm²
  stranded wire 0.5 ... 10 mm²
  others: solid wire 0.2 ... 4 mm²
  stranded wire 0.2 ... 2.5 mm²

Permissible ambient conditions

- operating temperature -10°C...+55°C
- storage temperature -25°C...+55°C
- transport temperature -25°C...+70°C
- humidity rating, yearly mean value <75%
  for 30 days 95% at <40°C
  moisture condensation not permitted

Mechanical strength

- resistance to earthquakes (IEC 255-21-3)
  nominal frequency range 1...35 Hz
  cut-off frequency 8...9 Hz
  horizontal 3.5 mm; 10 m/s²
  vertical 1.5 mm; 5 m/s²
- vibration strain (IEC 255-21-1, IEC 68-2-6)
  Fc: 10...150 Hz; 0.075 mm; 1g
- repeated impact strain
  (IEC 255-21-2) Ea: 11 ms; 15 g
  Eb: 16 ms; 10 g

Auxiliary power supply

- U_H depending on design 24-65.5 V DC
  or 60-137 V DC, 60-100 V AC
  or 110-320 V DC, 100-240 V AC
- operating range $0.8\text{-}1.1 \cdot U_H$
- power consumption <10 W
- stored energy time in case of auxiliary power failure, based on nominal voltage ≥ 50 ms

Measuring input circuits

- nominal frequency 50 Hz
- current paths (different terminals)
  rated current (In) 1 A / 5 A
  load capability
  permanent 5·In
  1 sec 100·In
  limiting dynamic value (10 ms) 250·In
  power consumption at In < 0.25 VA

Binary signal inputs (optocoupler) [1]

nominal input voltage (Vi) 24...220 V DC
power consumption $<4 \cdot 10^{-4} \cdot (Vi)^2$ W
logic low level <10 V

[1] On special-wish, differently from the default long-range input voltage inputs can be dimensioned for a Low/High switching voltage of about 60 V.

Output relays

- trip relays (marked S1, S2)
  switching voltage 250 V DC, AC
  limiting making capacity 1250 W (VA)
  limiting breaking capacity
  50...250 W (voltage- and load dependent)
  0.25 A at 220 V DC, L/R = 0 ms
  0.15 A at 220 V DC, L/R = 40 ms
  both contacts in series:
  0.25 A at 220 V DC, L/R = 40 ms
  S1: limiting continuous current
  1x8 A or 2x5 A /40°C
  S2: limiting continuous current 8 A
  limiting short-time current for 0.5 s 30 A
- signal relays (marked M1... M5)
  switching voltage 300 V DC, 250 V AC
  switching current 8 A
  switching capacity <2000 VA,
  50...220 W (voltage- and load dependent)
  limiting continuous current 6 A

Serial interface

- PC interface RS-232
  front panel 9-pin Sub-D connector
  electrical isolation (depending on design)
  0 kV / 1.5 kV
- IEC 60870-5-103 interface optional
  optical fibre connector F-SMA
  optical wavelength 850 nm
  distance <1 km
  permissible path attenuation <8 dB
  glass fibre 62.5/125 µm
  character neutral position light on
  or RS 485 half-duplex
  unit load 1
  potential separation 1.6 kV, 1 s
  connection terminal

Displays

- LED's green: 1; red: 1; yellow: 10
  states steady light, flashing, off
- LC display four-line display of
  20 alphanumeric characters each
  illuminated

Setting values and ranges (selection)

- thermal replica
  basic current 0.4...2.0·In
  operate factor k 1.00...1.20
  heating time constant τ 60...7200 s
  cooling factor 1.0...8.0
- starting and rotor blocking monitoring
  min. starting current $1.0...6.0 \cdot I_B$
  max. starting time at $6 \cdot I_B$ 3...120 s
  max. rotor blocked time 1...40 s
  number of permissible motor startings being the first one a cold start 1...6
- asymmetry of current I_{Lmax}/I_{Lmin} 1.05...2
- underload protection $0.2...1.0 \cdot I_B$
- current stages
  overcurrent stage $I_L>$ 0.2...25·In
  high current stage $I_L>>$ 2.0...40·In
  earth-fault current stage $I_E>$ 0.1...12·In
  stage $I_E>>$ 1.0...20·In
  resetting ratio 0.20...0.95
- definite-time stages $t_{IL}>$, $t_{IE}>$ 0.01...20 s
  $t_{IL}»$, $t_{IE}»$ 0.01...9.99 s

Routine testing

- dielectric test 2.5 kV, 50 Hz, 1 s
  exceptions: power supply 2.83 kV DC
  RS485 1.6 kV, 1 s
- Each protection relay will be subjected to a 72-hour alternate temperature test while in function.

Type testing

- impulse voltage 5 kV; 1.2/50 µs; 500 Ω
- dielectric test 2.5 kV, 50 Hz, 60 s
  exceptions: power supply 2.83 kV DC
  RS485 1.5 kV, 60 s
- Insulated PC interface 1.5 kV, 60 s
- EMC noise immunity EN 50082-2, severity class 3
  electromagnetic RF field
  magnetic field of power engineering frequency
  discharge of static electricity (ESD)
  fast transients (bursts)
  transients (surges)
  RF interference test (IEC 60255-22-1)
  transformer cross voltage 2.5 kV
- EMC emitted interference EN 50081-2 class B

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10 Order data DM 2

Pl.-No.: **1743 20- ---**

supply voltage: 7th digit [2]	
110 - 240 V DC/AC	0
60 - 137 V DC	1
24 - 65 V DC	2
type of housing: 8th digit	
panel surface-mounted	
CT terminals down	0
CT terminals right	2
CT terminals left	4
panel flush-mounted	
CT terminals down	1
CT terminals right	3
CT terminals left	5
IEC interface / language: 9th digit	
Fibre optical / German	0
Fibre optical / English	1
RS485 / German	5
RS485 / English	6
design: 10th digit	
	0
	6

design includes	0	6
binary inputs	2	5
trip relays	1	2
signal relays (1 CO)	2	2
signal relays (1 NO)	0	3
PC I/F electrically isolated	X	X
IEC60870-5-103 interface	-	X

Optocoupler inputs:

On special-wish, differently from the default long-range input voltage optocoupler inputs can be delivered with a Low/High switching voltage of about 60 V.
This wish is separated with order to declare.

[2] for complete voltage range see Specifications

Accessories

PC-protector interconnecting cable

Pl. No.: 1743 900 010

COMM-3 PC operator software

- Management program

Pl.-No.: 1744 990 00-

Variant: 10th digit	
Full-version	0
Upgrade from COMM-2 to 3	1
Update of COMM-3	2
Demo version	9

- Device programs

Pl.-No.: 1744 991 ---

Type of device: 8th and 9th digit	
all devices [structure versions]	0 0
DM 2 [1004]	1 0
DSRZ(W) 2 [2001]	2 0
DSZ(W) 2 [3007]	3 0
DSZW 4 [3105]	3 1
DSZ 4 [3205]	3 2
DQ2S 2, DQ3S 2 [4008]	4 0
DD 2 [5033]	5 0
P9x-DD.. 6 [5601]	5 6
DDS(E) 2 [6002]	6 0
DSRZE 2 [7000]	7 0
P9x-DS.. 6 [7604]	7 6
Variant: 10th digit	
current structure version	0
old structure version	1

When reordering a device program the structure version number of the device is necessary additionally (see label on device). Example for DSZ 2, old structure version 3001:
Pl.-No. 1744 991 **301- 3001**

SDA 2 graphics software

Pl.-No.: 1744 992 000

On supplied CDROM the user manual exists as a PDF-file.

User manual COMM-3, SDA 2 printed version

Pl.-No.: 1744 993 0--

Language: 9th digit	
German	0
English	1
Manual: 10th digit	
COMM-3	0
SDA 2	1

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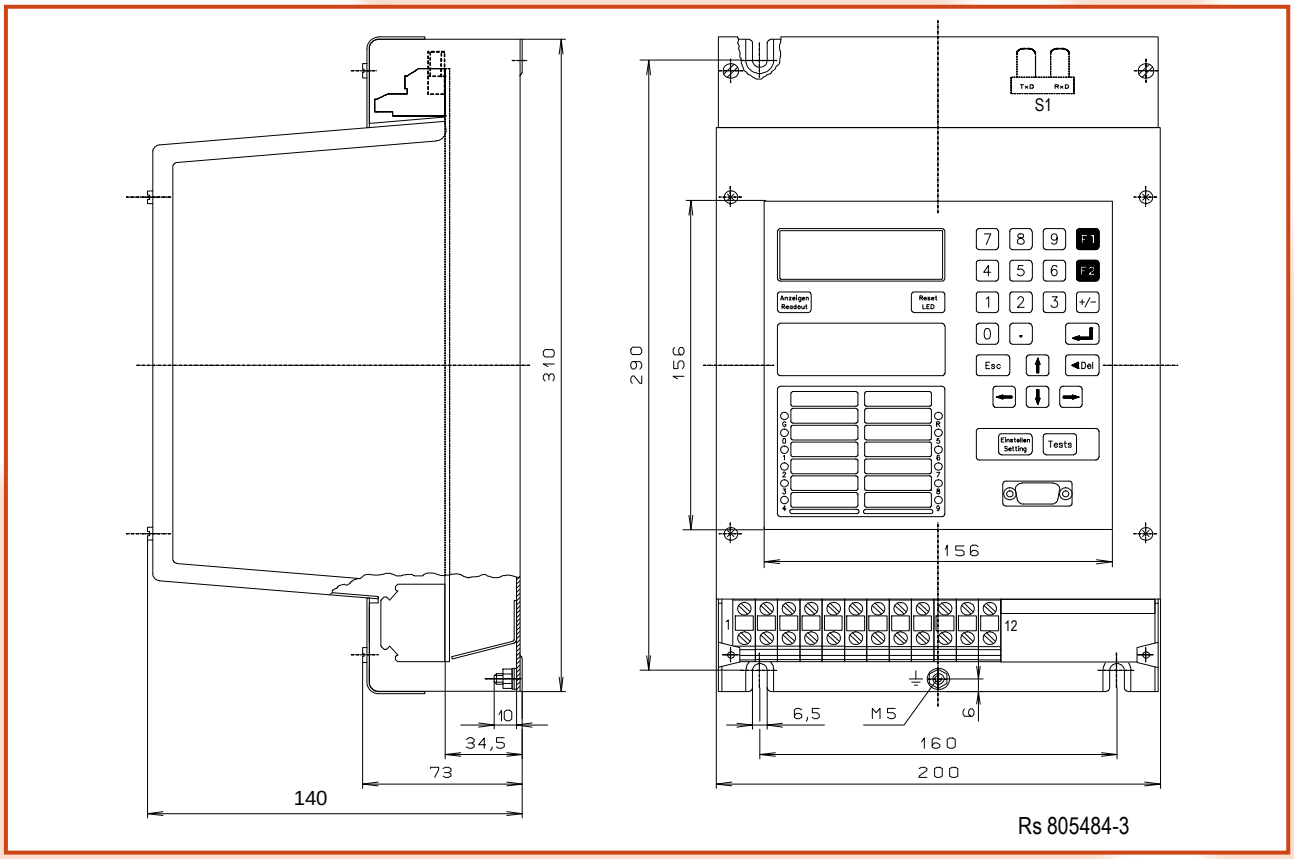

Fig. 4: DM 2 housing for panel surface-mounting, lower terminal cover not shown in top view. With the horizontal models the keypad is turned + or -90°.

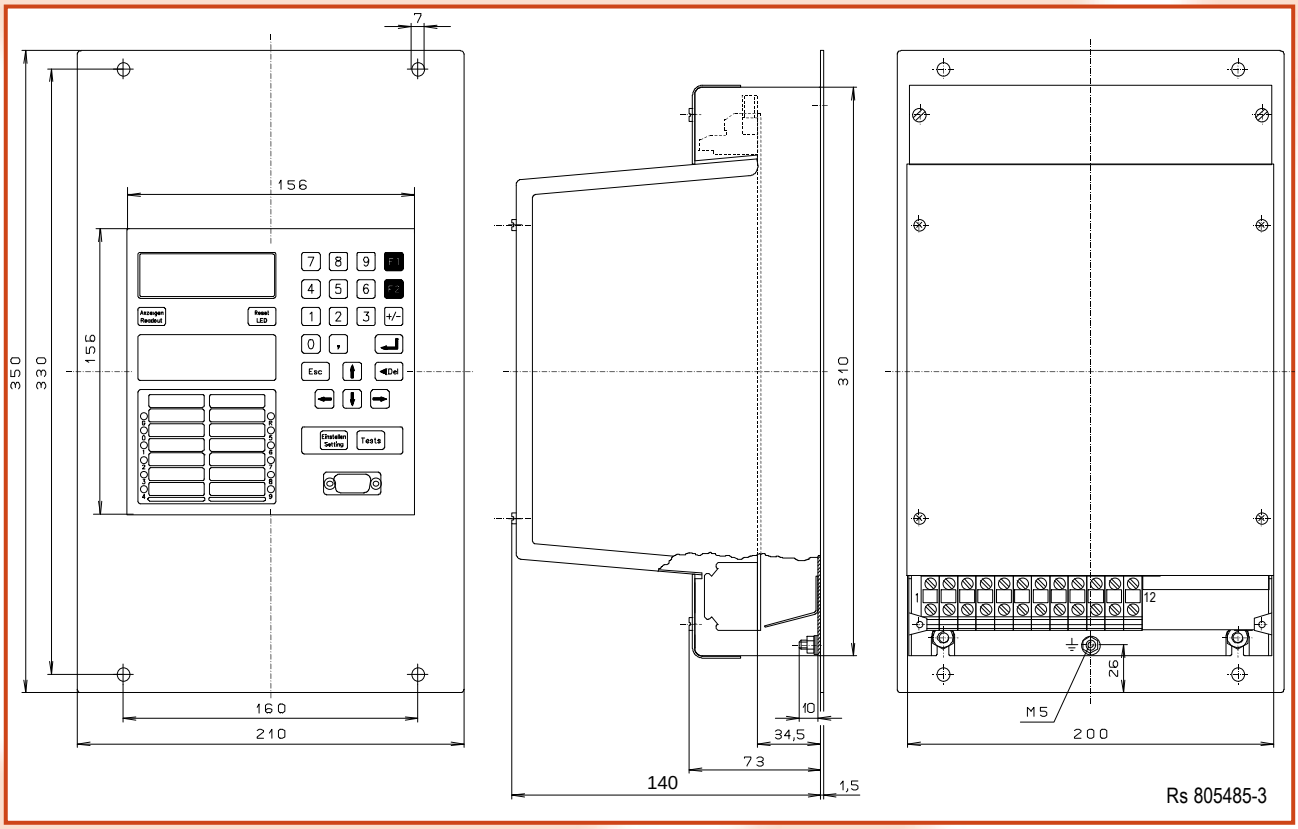

Fig. 5: DM 2 housing for panel flush-mounting, lower terminal cover not shown in rear view (right-hand side). The panel cut-out should be 202 mm * 312 mm when device will be put through from front side.
With the horizontal models the keypad is turned + or -90°.

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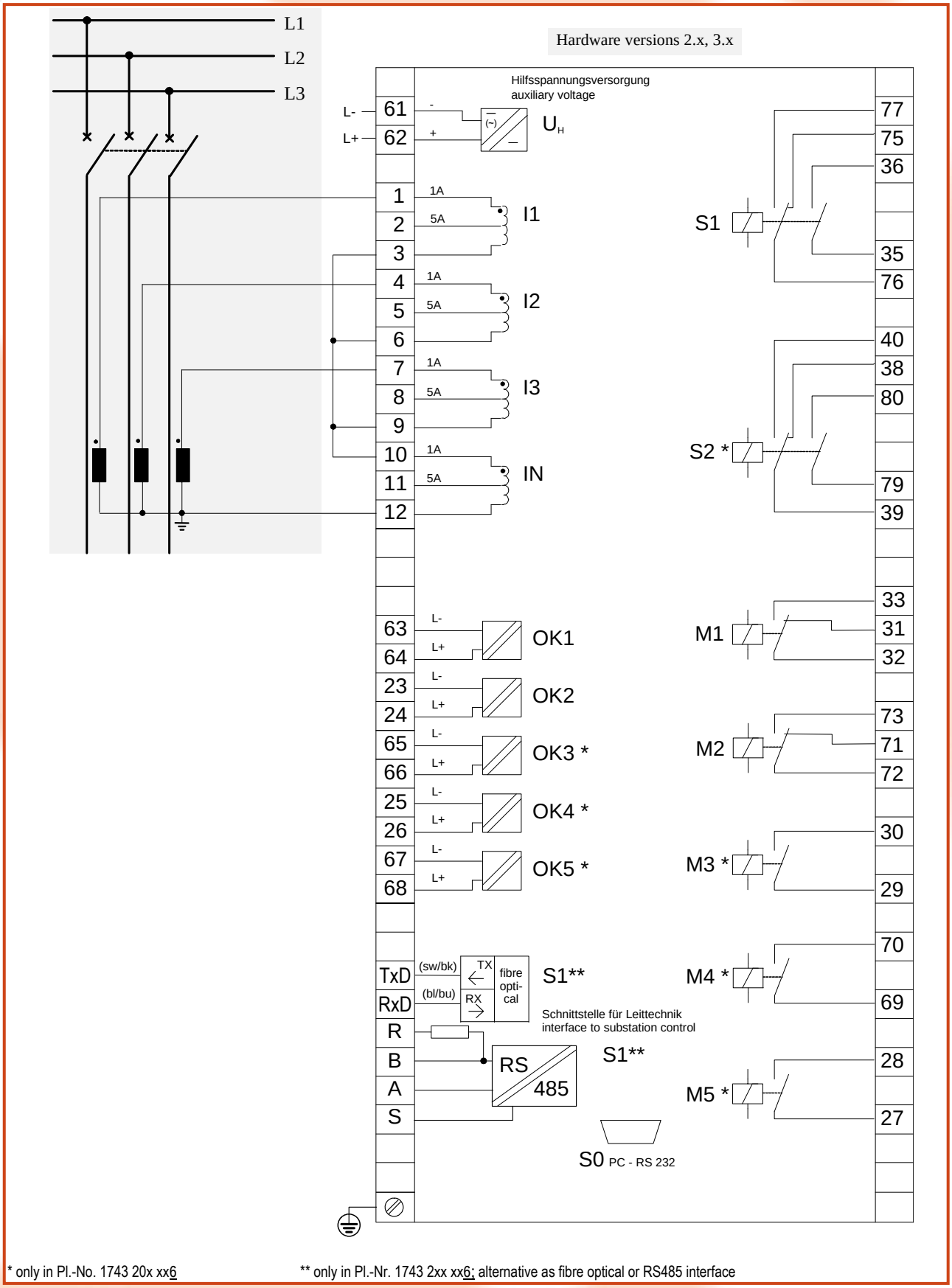

* only in Pl.-No. 1743 20x xx6

** only in Pl.-Nr. 1743 2xx xx6; alternative as fibre optical or RS485 interface

Fig. 6: Terminal assignment of DM 2

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