



Operating Manual

Transformer-Monitor



Feature TM1 of REG-D™

Feature T1 of REG-DA

Transformer-Monitoring-Module TMM for upgrade

Table of Contents

1.	User guidance	4
1.1	Target group	4
1.2	Warnings	4
1.3	Tips	5
1.4	Other symbols	5
1.5	Applicable documentation	5
1.6	Storage	5
2.	Scope of delivery	5
3.	Safety instructions	6
4.	Basic description of the Transformer Monitor	7
4.1	Activation of the Transformer Monitor on the REG-D(A)	13
4.2	Monitor	14
4.2.1	Oil temperatures (TC/Transformer)	15
4.2.2	Winding currents and winding temperature	15
4.2.3	Oil level (TC/Transformer)	15
4.2.4	Overload Prediction	15
4.3	Service life	16
4.3.1	Operating hours (1)	16
4.3.2	Operating hours (2)	17
4.3.3	Loss of life (IEC)	18
4.4	Statistics	20
5.	SETUP	21
5.1	SETUP 1: Regulation	21
5.1.1	Transformer Parameters	21
5.1.2	Regulation base	24
5.1.3	Temperature limits	24
5.1.4	Programming/Setup of the control inputs and outputs	25
5.2	Analog Channels	27
5.2.1	Analog in- and outputs	27
5.3	SETUP 2: Regulation	29
5.3.1	Calculation	29
5.3.2	Fan assignment	30
5.3.3	Number of fans	31
5.3.4	Current measurement	31

5.4	SETUP 3: Alarm.....	32
5.4.1	Oil temperature (TC)	33
5.4.2	Oil level (TC)	33
5.4.3	Oil level (transformer).....	34
5.5	SETUP 4: Alarm.....	35
5.5.1	Oil temperature (Alarm)	35
5.5.2	Winding temperature (Alarm)	36
5.5.3	Winding temperature (Trip).....	36
5.6	SETUP 5: Alarm Water and Gas in oil.....	37
5.6.1	Water in Oil content.....	37
5.6.2	Gas in Oil (Total gas in Oil) content.....	37
5.6.3	H2 (Hydrogen) in Oil content	38
5.6.4	CO (Carbon Monoxide) in Oil content.....	38
5.7	SETUP 6: Lifetime	39
5.7.1	Lifetime Transformer	39
5.7.2	Lifetime Tap changer	40
5.7.3	Lifetime Oil pump.....	40
5.7.4	Lifetime Fan.....	41
5.8	SETUP 7: Overload	41
5.8.1	Max. Winding temperature	41
5.8.2	Time to max. temperature	41
6.	Retrofit of analogue channels (only REG-D™ and TMM)	42
7.	Increasing the system's hardware resources	45
7.1	Additional inputs and outputs	45
7.2	COM3/Modbus (RTU Master) Converter	47
8.	Temperature measurement.....	48
8.1	Accuracy considerations	48
9.	Warranty	49
10.	Test report	49

1. User guidance

This user manual contains a summary of the information needed for installation, commissioning and operation.

Read the user manual entirely and do not use the product unless you have understood its content.

1.1 Target group



The User Manual is intended for skilled technician's as well trained and certified operators.

The contents of this User Manual must be accessible to people tasked with the installation and operation of the system.

1.2 Warnings


Structure of the warnings


Warnings are structured as follows:


 SIGNAL WORD	Nature and source of the danger. Consequences in the event of non-observance.
	 Actions to avoid the danger.

Types of warnings

Warnings are distinguished by the type of danger they are warning against:

 DANGER!	Warns of an immediately impending danger that can result in death or serious injuries when not avoided.
--	---

 WARNING!	Warns of a potentially dangerous situation that can result in death or serious injuries when not avoided.
---	---

 CAUTION!	Warns of a potentially dangerous situation that can result in fairly serious or light injuries when not avoided.
---	--

NOTICE:	Warns of a potentially dangerous situation that results in material or environmental damage when not avoided.
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1.3 Tips



Tips on the appropriate use of the device and recommendations.

1.4 Other symbols

Instructions

Structure of the instructions:

- ➡ Instructions for an action.
- 👉 Indication of an outcome, if necessary.

Lists

Structure of unnumbered lists:

- List level 1
- List level 2

Structure of numbered lists:

- 1) List level 1
- 2) List level 1
 1. List level 2
 2. List level 2

1.5 Applicable documentation

For the safe and correct use of the product, observe the additional documentation that is delivered with the device/software as well as the relevant standards and laws.

1.6 Storage

Store the user manual, including the supplied documentation, readily accessible near the device.

2. Scope of delivery

- Software module TMM (integrated into the firmware of REG-D(A))
- License key for releasing the software feature in the REG-D(A) (if necessary)
- Analogue input module (mA or PT100 module, depending on the order)
- Operating manual

3. Safety instructions

- Follow the operating instructions.
- Keep the operating instructions with the device.
- Regularly instruct staff in all relevant issues regarding occupational safety, the operating instructions and, in particular, the safety instructions they contain.
- Ensure that the device is only operated if in perfect condition. Never use a damaged device (physically damaged or malfunctioning).
- Ensure the device is only operated by qualified personnel.
- Connect and use the device only as specified.
- Operate the device only with the recommended accessories.
- Ensure that the device is operated only in its original condition.
- Ensure that the device is only operated within the permissible rated data
- Do not install or operate the device in environments where explosive gases, dust or vapours may be present, i.e. that generally do not meet the requirements mentioned in the technical datasheet.
- Clean the device only with cleaning products that comply with the manufacturer's specifications.
- Use only spare parts and auxiliary materials that have been approved by the manufacturer.
- Maintenance and repair of an open REG-D(A) Relay for Voltage Control & Transformer Monitoring (plug-in module without housing) must only be carried out by authorised, qualified personnel and must satisfy EMC Directives.
- No supply or control voltage should be applied to a disassembled plug-in module, e.g. open (disassembled) REG-D(A) Relay for Voltage Control & Transformer Monitoring, as electrical parts carrying dangerously high voltages could be encountered.

NOTICE:

Please note that these operating instructions may not always contain the latest information concerning the device. Should you require a more recent version of these instructions or have any questions about the product or how to use it, please contact the REGSysTM Support on:
+49 (0)911 628108-101 or via email at: regsys-support@a-eberle.de.

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4. Basic description of the Transformer Monitor

Power transformers are key components of an electrical supply grid. The failure of a transformer not only has major economic consequences for the energy supplier, it can also lead to serious losses for consumers. For this reason, it makes sense to monitor the transformer as closely as possible, to record its 'temperature curve' (the thermal image) and to collect information about the current load and the expected remaining service life as well as the moisture content of the oil and the paper. This task can - based on IEC standards - be solved by electronic measuring and computing facilities.

This operating manual describes the concepts and the measurement principles behind the TMM functionality which is available for the REG-DTM and the REG-DA. It also describes how the software and the hardware of a REG-D(A) can be upgraded to enable TMM functionality in addition to performing its role as a voltage regulator. Also the steps required to set up the transformer monitoring functions are described in detail.

The winding's hot-spot temperature is determined by the current that runs through the windings and the oil temperature. The latter can be fed into the REG-D(A) as a mA signal or directly as a PT100 signal. Appropriate input modules are available for both types of signals. The appropriate analogue input channels must be available in order to record the fill levels and other quantities such as humidity, H₂ or the oil's CO content.

These channels can be also added to the REG-DTM on side.

It is not possible to upgrade REG-DA at a later date therefore if TM is required this must be specified at time of ordering. For safety and warranty purposes disassembly of REG-DA is not permitted.

Monitoring consists of monitoring the transformer's main parameters. The oil temperature is recorded in addition to the current. The hot-spot temperature is determined from the oil temperature and the current in accordance to IEC 60354 or IEC 60076 and extrapolated to the transformer's service life consumption. Up to six cooling stages can be activated depending on the oil or winding temperature. The system monitors the operating times of the fan and controls the individual fan groups so that as balanced an operating time as possible is achieved over the whole operating life. If desired, individual fans can also be permanently assigned to a specific cooling stage. Additional alarms such as Buchholz pre-warning and/or Buchholz triggering can be fed into the monitoring system as binary signals, displayed and sent to a SCADA system for further processing (see Figure 1).

The following SCADA protocols are available:

- IEC 61850
- IEC 60870-5-101
- IEC 60870-5-103
- IEC 60870-5-104
- DNP 3.0 / DNP 3.0 over Ethernet
- MODBUS RTU / TCP
- SPABUS
- PROFIBUS

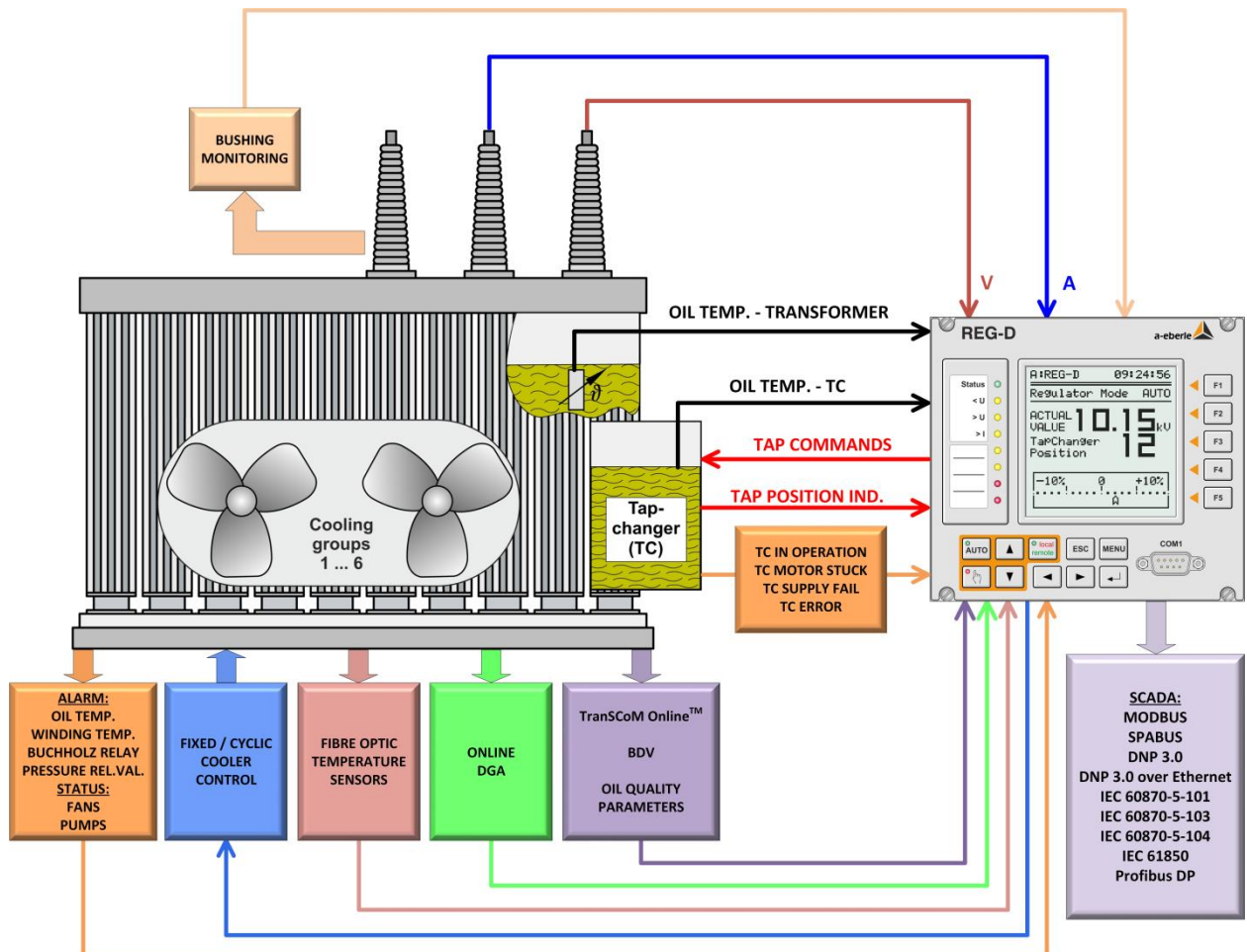


Figure 1: Signal diagram

The thermal situation in the transformer can be displayed in a graphic (see Figure 2). Please note that it is a simplified view of a complex situation. The 'simplification' is based on the following assumptions:

- the oil temperature in the tank increases linearly from the bottom to the top
- the average temperature of the winding is linearly parallel to the oil temperature with a constant temperature differential g_r increasing from bottom to top
- the hot-spot temperature (P) is higher than the temperature of the winding at the upper (hot) end of the winding. The increase in temperature between the hot spot in the winding and the oil temperature at the top of the tank is specified as constant H_{gr} (hot spot to top oil gradient). Studies have shown that the factor H can vary between 1.0 and 2.1 based on the size, short-circuit impedance and winding design of the transformer.

The abbreviations used in the diagram are explained below. Measured values are indicated by a solid square (■), calculated values are indicated by a solid point (●).

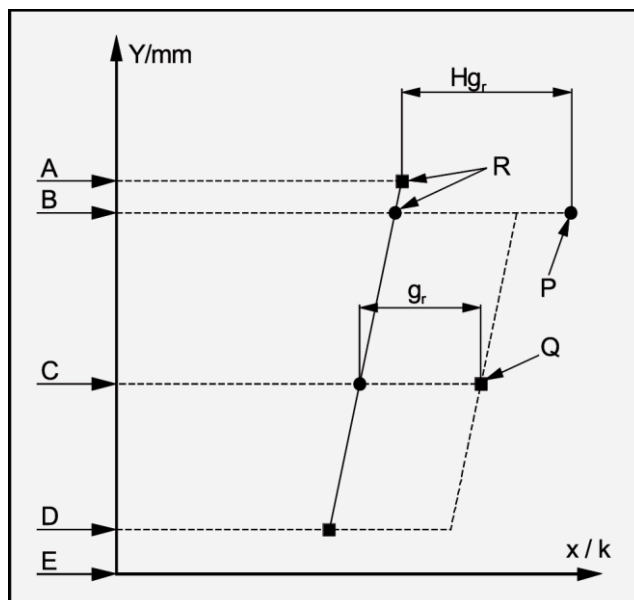


Figure 2: Thermal model based on IEC

- A Temperature of the top oil layer
- B Temperature in the transformer tank at the upper end of the winding
- C Temperature of the tank's oil at the centre of the winding
- D Temperature at the lower end of the winding
- E Represents the bottom of the tank
- P Hot-spot temperature
- Q Average winding temperature
- R Points that are assumed to be at the same temperature
- X X-axis of the graph shows the temperature
- Y Y-axis indicates the relative position of the individual points

The basic version has only one current input to determine the hot-spot temperature. Three currents can also be measured through an optional Aron circuit (hardware Characteristic M2).

In most cases, this configuration will produce acceptable results because one can assume that the transformer has a more or less balanced load.

For this general operating condition: $I1 \sim I2 \sim I3$

The hot-spot temperature is calculated and the cooling equipment controlled according to the model shown in Figure 3.

The operating current and the oil temperature are the most important measurements for the estimation and calculation of the hot spot and the hot-spot temperature Θ_h . The values of the measured oil temperature together with the current and characteristic values of the transformer are put into the equation to obtain a thermal image of the transformer. This enables the service life consumption of the insulation and the hot-spot temperatures to be calculated.

The transformer's temperature can be controlled by connecting fans in six stages, two oil pumps and a heater. The fans are controlled automatically based on the oil-, winding or predicted winding temperature. The outputs used to control the fans and the inputs used to feed the temperature signals into the controller can be set up at a later stage in the menu-driven configuration.

A default configuration is supplied that may occasionally require a few minor changes.

If additional analogue inputs or outputs and/or additional binary inputs or outputs are required for the Monitoring system, interface modules (ANA-D and BIN-D) can be connected through the device's COM 3 port. This increases the hardware resources of the basic unit.

If the information provided by the system is used properly, the function can significantly increase the transformer's availability using comparatively few resources.

Block diagram of the hot-spot calculation and the cooling stage control

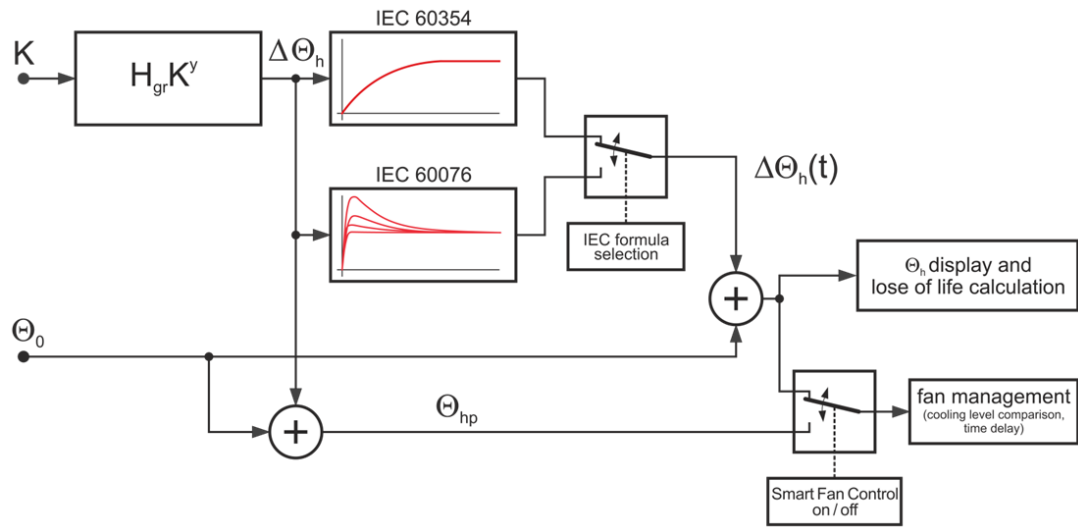


Figure 3: Block diagram

K : Load factor = I / I_N
 Θ_0 : Oil temperature (measured)
 H_{gr} : Hot-spot to top-oil gradient
 $\Delta\Theta_h$: Hot-spot temperature increase
 Θ_h : Hot-spot temperature
 Θ_{hp} : Expected hot-spot temperature
 Y : Winding exponent

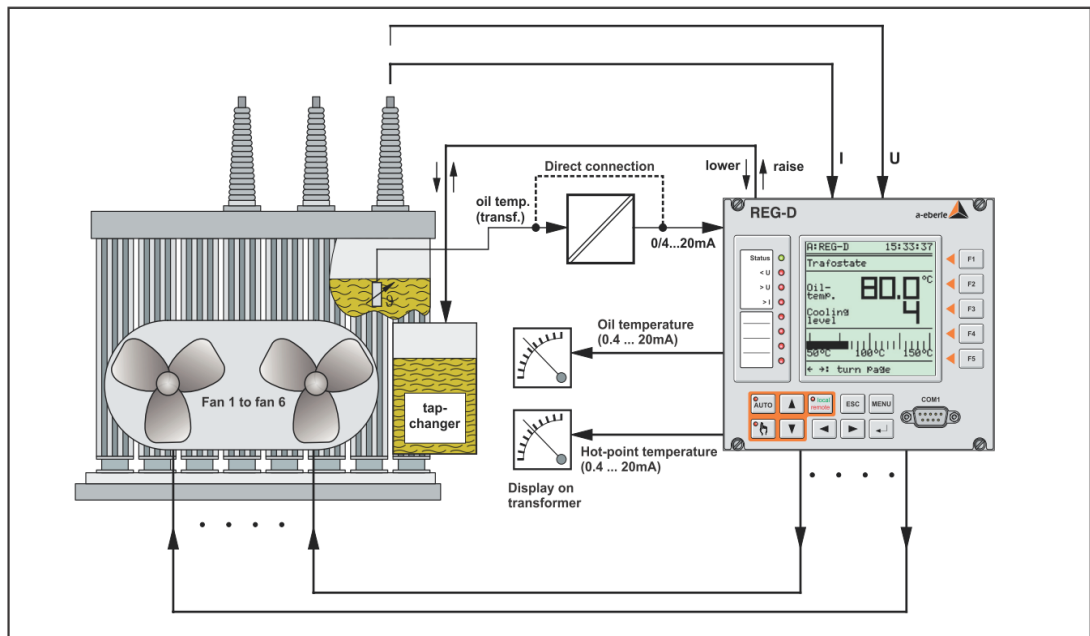


Figure 4: Oil temperature measurement diagram

If a temperature transducer has already been allocated to measure the oil temperature, the oil temperature can be fed into the controller as mA input. If necessary, the PT100 temperature sensors can also be connected directly in a three-wire circuit.

If remote temperature gauges are used, both the hot-spot temperature and the oil temperature can be provided as mA output.

The oil or hot-spot temperature function enables up to six groups of fans, two oil pumps and a heater to be connected.

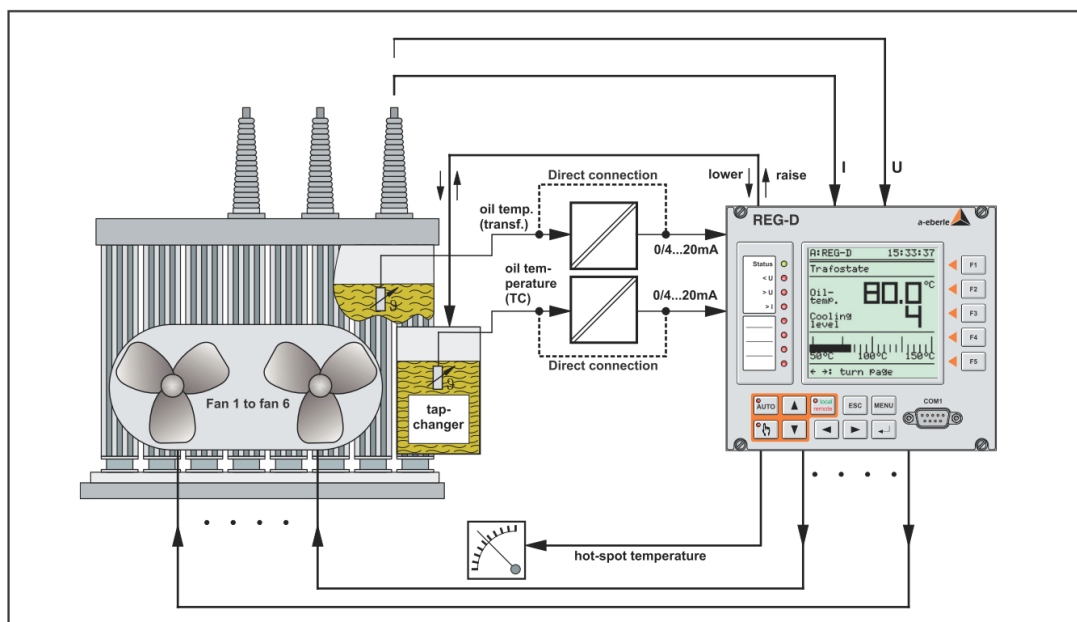


Figure 5: Diagram of the oil temperature measurement in the tap changer

If the oil temperature in the tap changer vessel is also to be recorded, a second mA or PT100 input must be available.

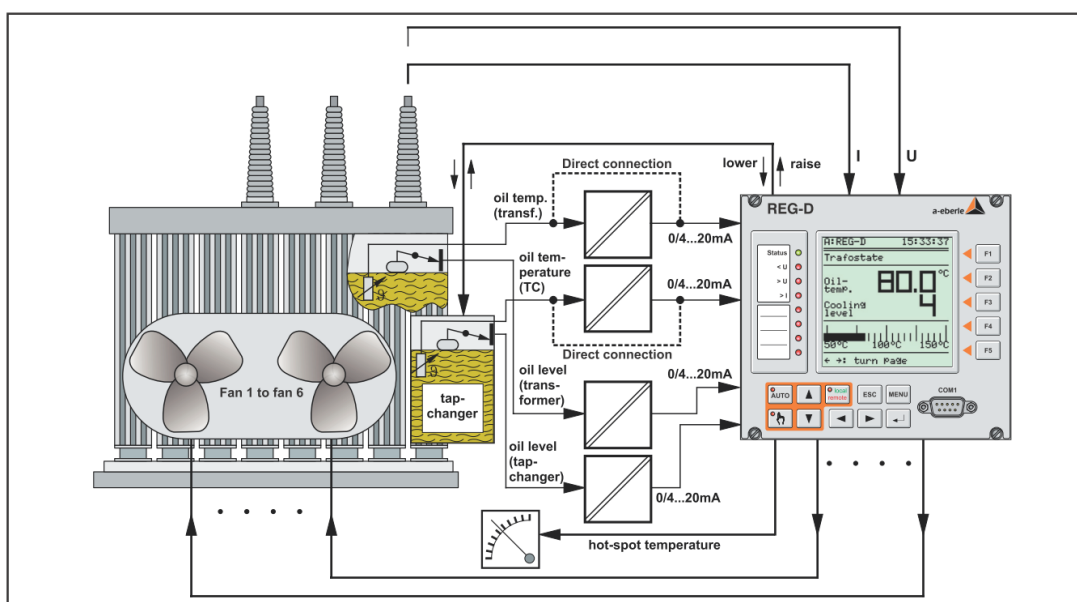


Figure 6: Fill level determination diagram

The fill levels of the transformer and/or tap changer can also be recorded and fed into the controller. The information can be displayed on the Control unit's screen and if necessary transferred to a SCADA system (Figure 1).

4.1 Activation of the Transformer Monitor on the REG-D(A)

The Transformer Monitor is a part of the REG-D(A) firmware and it is managed with the software feature TM. By activating and deactivating the feature TM the Transformer Monitor function is switched on and off.

To activate the feature TM a key code is necessary. This code will be delivered if the TMM (retrofit of an existing REG-D(A)) package is ordered. The feature TM can then be released with the service tool of the Software WinREG (from version 3.9.7) or in future with the AE Toolbox software.

If the REG-D(A) is ordered directly with the Transformer Monitoring feature (order feature T or TM) then there is no additional key code necessary. The function is then already enabled at delivery.

To release the Transformer Monitor on an existing REG-D(A) it's not automatically necessary to do a firmware upgrade. This depends on the already installed firmware version. But in most cases it makes sense to update the firmware to have the full functionality of the latest version of the Transformer Monitor available.



Firmware version and update

This manual describes the state of the transformer monitor in the REG-D (A) firmware version 2.23. Should you use a different firmware version is an aberrant functions may arise. In general a firmware update to the latest version can be carried out on every REG-D(A). For this purpose, please refer to the notes for the firmware update in the user manual of the REG-D(A).

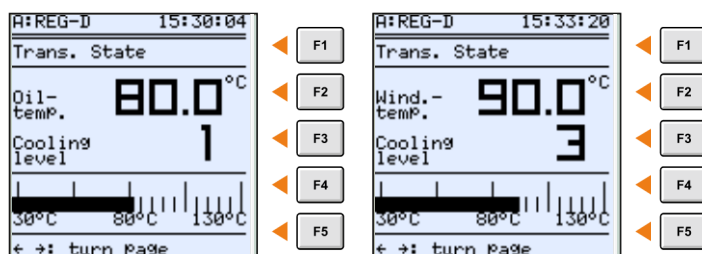
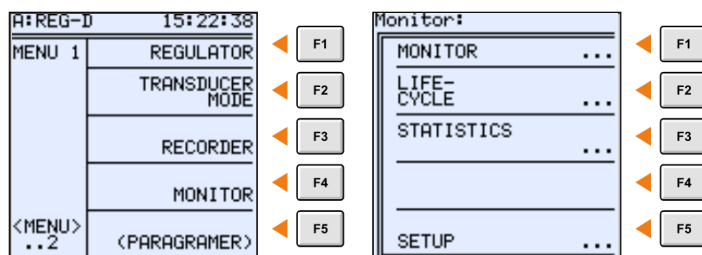
4.2 Monitor

In the main menu (press <Menu>), select the Monitor function with the <F4> function key. Press F1 to select the monitor indication.

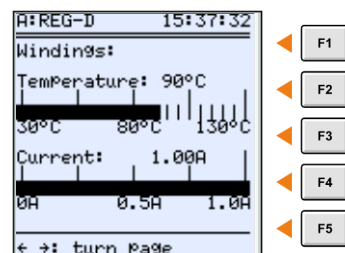
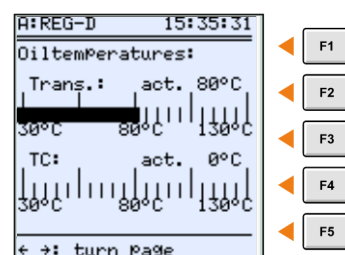
The Monitor's basic screen shows either the oil temperature or the winding temperature as decimal values and a bar graph. The current cooling stage is also displayed.

The oil temperature is displayed whenever the oil temperature is selected to regulate the temperature, the fan and the oil pump control. The winding temperature is displayed when either the 'Smart Fan Control' (SFC) or the winding temperature is selected as the basis for the temperature control.

Based on the model, transformers are equipped with several fan groups. Since the fans are similar in terms of their cooling performance, a greater cooling performance is achieved by running several fans at the same time. Cooling stage 3 means that three groups of fans are working at the same time. Cooling stage 1 means that one group of fans is working.



Press '→' to access the next two screens. These screens display either the oil temperature for the transformer and the tap changer or the hot-spot temperature and the load current flowing through the windings.



4.2.1 Oil temperatures (TC/Transformer)

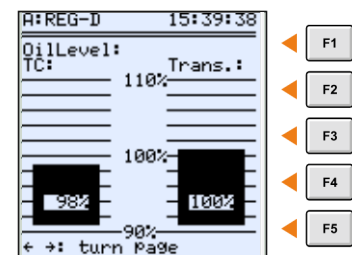
The temperature can either be displayed as bars or numerically. With the help of the setup menu the maximum temperatures for the transformer and the tap-changer can be set. If the temperature in the tap-changer tank is required, a mA value has to be supplied to the voltage regulator via an analogue input.

4.2.2 Winding currents and winding temperature

The “windings” display mode provides information on the present current flowing through the windings and the hot-spot temperature calculated from it or provided from a winding temperature measurement device like the REG-FO.

4.2.3 Oil level (TC/Transformer)

Press '→' to access the next screen and display the fill levels for the transformer tanks and the TC vessel (TC ⇒ tap changer). The oil level in the transformer and the tap changer can only be displayed if the controller is supplied with the corresponding sensor data from the transformer and the tap changer. In the simplest case, the fill level is supplied to the controller as an analogue signal. Scaling is done from the menu. The bar flashes when the limits are exceeded. In addition the level alarm is available as relay and LED output function as well as SCADA indication. A black non-flashing column indicates that the 'fill level is OK'.



4.2.4 Overload Prediction

Press '→' to access the next screen and display the possible overload and the time within which the over temperature will be reached.

Possible overload

This screen provides information about the transformer's load capacity. It indicates the load that the transformer can carry as a percentage without exceeding the maximum winding temperature at the end of the window (Time to max temperature).

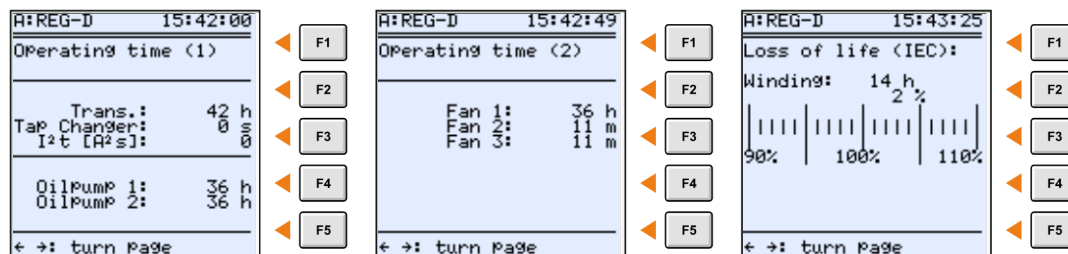
Time to over temperature

This screen displays the time after which the maximum winding temperature will be reached at the current load.

Two dashes are displayed if the temperature limit is not reached at the current load. The same applies when the temperature limit has already been reached or exceeded.

4.3 Service life

The 'SERVICE LIFE' menu, which combines all of the service lives (transformer, fan, pumps), is accessed from the 'MONITOR' main menu by pressing <F2>.



4.3.1 Operating hours (1)

'Operating hours 1' displays the accumulated operating hours for the transformer (transformer under voltage), the tap changer and the oil pump. The operating hours for the transformer and the tap changer are different because only the hours that the motor is in operation are measured for the tap changer. The 'Operating light time' is used as an indicator of the tap changer's operating hours. This means that the service life counter is only active for the tap changer if a binary input is configured as 'TC in operation' (07:TC.i.Op).

The counter value does not change if an input is configured but no 'TC in operation' signal connected. If a binary input is not configured, the program uses the 'Maximum Time TC in operation' setting in the Controller's SETUP 5 menu (Functions..., F1).

In this case, the tap changer's service life counter is incremented by the preset time when the controller issues a control command.

The transformer's operating hours are recorded by default if a voltage on the secondary page is set to 'Transformer in operation'.

This approach can produce incorrect results (see Figure 7) based on the location of the voltage transducer.

In any case, measuring the primary voltage of the transformer will produce correct results. The firmware characteristic 'Three winding' can be used to activate a second voltage channel that measures the primary voltage. The second voltage input is always present and in principle available for this task when the controller is equipped with hardware Characteristic 'M9'. In all other cases, the regulator – if the primary voltage is to be measured – must be sent in for modification.

If software feature 'Three winding' is activated (only possible in combination with hardware Characteristic M9), the operating hour count is derived from the primary voltage.

If the feature 'Three winding' is not activated, the operating hours are derived from the transformer's secondary voltage, which - as mentioned above - can produce incorrect results based on the location of the voltage transducer.

Figure 7 shows an application in which two transformers are fed from a bus bar.

If the voltage transducer is installed close to the bus bar, the controller will still measure a voltage if the secondary voltage of transformer T1 is switched off because the bus - and thus the voltage transducer - is supplied through the second active transformer T2.

Figure 8 displays the secondary control voltage, while the voltage for the operating hour count is tapped from the primary voltage transducer. This version records the operating hours correctly.

The value I^2t is used to estimate the contact erosion in the tap changer. Two parameters are needed to determine this value. One is the current in the electric arc and the other the time 't' during which the arc is discharged. Current 'I' is the current that is flowing at the time of the changeover, whereas time 't' can be entered for a specific tap changer. It should be noted that the changeover time is very difficult to determine accurately and is also not constant over the life of the changer. But the accumulation of I^2t provides a way to capture the qualitative condition of the tap changer. If time 't' is set to 1, the sum of product I^2t is only I^2 .

If the oil pumps are controlled by the controller, the operating time of the pump is summed up and displayed in the menu.

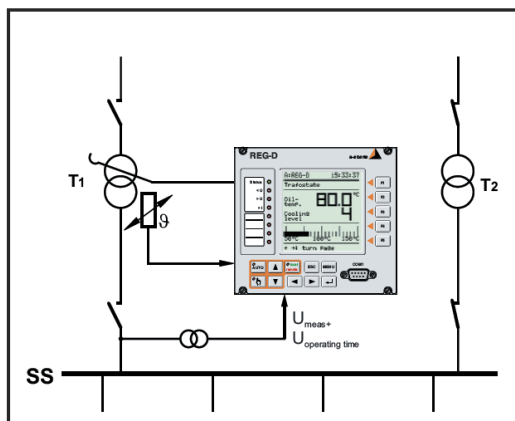


Figure 7: secondary voltage measurement

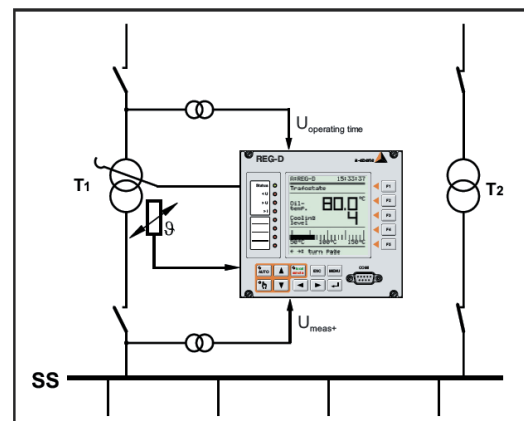


Figure 8: primary and secondary voltage measurement

4.3.2 Operating hours (2)

The operating times of the fan and the oil pumps are listed under 'Operating hours (2)'.

The fans are controlled according to an algorithm that always activates the fan with the smallest total operating time. This ensures that all the fans are more or less evenly loaded over time. It's also possible to assign a certain cooling stage to a certain relay output (no operating hour equalisation).

The oil pumps are fixed assigned to a digital output (no operating hour equalisation)

4.3.3 Loss of life (IEC)

The loss of life information is derived from the equations specified in IEC 60354 or IEC 60076-7.

The loss of life should not be confused with the operating hours described earlier. The 'Operating hour' log file only counts the time during which the transformer is under voltage, while the loss of life takes thermal ageing into account.

The relative thermal ageing of the insulation as a factor of temperature and time is determined by the Arrhenius equation:

$$\text{loss of life} = e^{(\alpha+\beta)/T}$$

α and β : Constants that are determined by tests on the insulators

T : Thermodynamic temperature in K

In the 80... 140°C temperature range, the Arrhenius equation can be replaced with the slightly simpler Montsinger relationship.

$$\text{loss of life} = e^{-P\Theta}$$

P : Constant

Θ : Temperature in °C

According to scientific publications, a transformer's service life consumption doubles in the 80 to 140°C range when the temperature increases by about 6 K.

Another equation can be used to determine the relative service life consumption at temperature Θ_h relative to the normal service life consumption at temperature Θ_{hN} .

$$V = \frac{\text{loss of life at } \Theta_h}{\text{loss of life at } \Theta_{hN}} \quad (1)$$

$$V = 2^{(\Theta_h - \Theta_{hN})/6} = e^{0,693(\Theta_h - \Theta_{hN})/6}$$

The value Θ_{hN} was specified for a transformer according to CEI/IEC 60354 Part 1/11.71 at 98°C. This temperature corresponds to the operation of a transformer with nominal output at a coolant temperature of 20°C when the hot-spot over temperature is 78 K, i.e. 13 K above the average over temperature of 65 K. These temperature conditions correspond to the normal ageing of the insulation.

The following equation can be derived in common logarithms from equation (1) with $\Theta_{hN} = 98^{\circ}\text{C}$.

$$V = \text{Relative loss of life} = 10^{(\Theta_h - 98)/19,93} \quad (2)$$

This relationship is shown in the below table:

Θ_h in $^{\circ}\text{C}$	Relative service life consumption
80	0.125
86	0.25
92	0.5
98	1.0
104	2.0
110	4.0
116	8.0
122	16.0
128	32.0
134	64.0
140	128.0

Example:

10 hours at 104°C and 14 hours at 86°C consume $(10 \text{ h} \times 2) + (14 \text{ h} \times 0.25) = 23.5$ hours during an operation period of 24 hours.

Note that the service life consumption is negligible below 80°C .

When the load and ambient temperature are constant, the relative service life consumption is calculated with the relationship $V \times t$. 't' is the time under load and V is the relative service life consumption from equation (1).

More commonly, when the operating conditions are not constant, the transformer's service life consumption is calculated according to the following equation:

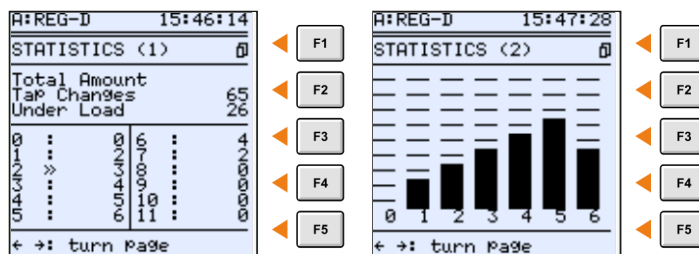
$$L = \frac{1}{t} \int_{t_1}^{t_2} V dt \quad \text{or} \quad L = \frac{1}{N} \sum_{n=1}^N V$$

n : Number of a time interval

N : Total number of the same time intervals

4.4 Statistics

Please press the <ESC> button (alternatively <MENU> and <F4>) to go to the Monitor Main screen. All the tap changer's activities are recorded in Statistics < F3 >.



The total number of tap changes (65 in the example) and the total number of tap changes under load (26 in the example) are recorded in STATISTICS –1.

This mode also provides information about which tap has been changed and how often.

These statistics give detailed information on the transformer setting.

Example: If there are only three or four tap positions in use, it usually indicates that either the permissible deviation or the time factor for the control is not optimally adjusted.

An improvement in the settings leads to a reduction of the switching operations and therefore to longer maintenance intervals under certain circumstances.

The situation shown above can be analyzed as follows:

- The tap changer was in operation 65 times in total, where only 26 switching operations were carried out under load.
- The tap changer is currently in position 2 and a current is flowing which is larger than 5% of the set current.



Load current indication by the double arrow

The double arrow symbol turns into a single arrow symbol if the current is below 5% of the nominal current.

A second type of display can be selected by pressing < F1 >.

The historical graphics in STATISTICS -2 give the operator a qualitative impression of the operations of the tap changer. The data is taken from the recordings in STATISTICS –1.

5. SETUP

- Press <ESC> (alternatively <Menu> and <F4>) to return to the main monitor menu and then press <F5> to enter the setup.

5.1 SETUP 1: Regulation

- Use the <F2...F5> keys to access the individual sub-menus.

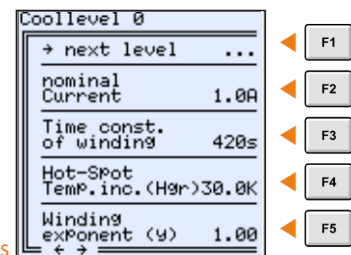


5.1.1 Transformer Parameters

A parameter set can be specified for each cooling stage. The number of menus depends on how many cooling stages/fans the transformer has. The number of cooling stages can be set via menu.

- Press <F1> to access the next set of cooling stage parameters.

... several sets of parameters



5.1.1.1 Rated current

The winding's rated current can be different for each type of cooling. Please note that primary values are also used for the rated current when measuring the primary current.

The rated current displayed in this menu must not be confused with the rated value of the current that is used to measure tasks in the controller (SETUP 5, F2 et sq.).

There, the rated current is configured as 1 A or 5 A. For transformer monitoring, the nominal value of the current is the maximum current a transformer can be subjected to with a specific cooling.

The current can be displayed in a range from 0...3000 A.

- Press <F2> to enter the corresponding rated current.
- Use <F1...F5> to enter the appropriate values.
- Press <Enter> to confirm the setting.

5.1.1.2 Thermal time constant of the winding

The thermal time constant is a transformer-specific parameter and can generally be taken from the transformer's data sheet.

Value range: 0...50000 s

You may need to contact the manufacturer.

The time constant for the winding is the time that would elapse until the hot spot reaches the steady-state final value divided by five.

Example:

With a time constant of 3000 seconds, it is assumed that after $5 \times 3000 \text{ s} = 15,000 \text{ s}$, meaning about 4 hours, the steady-state final value of the hot-spot temperature will be reached.

The number of submenus is determined in proportion to the number of predefined cooling stages. 'Cooling stage 0' means that there is no cooling at all. 'Cooling stage 0 (oil pump)' only appears when one of the two cooling types is configured ON/OF or ON/OD. The parameters for each of the cooling stages (fan group) are set for the transformer in the 'Cooling stage 1,2,...' menus.

5.1.1.3 Hot-spot temperature increase H_{gr}

The hot-spot temperature increase (Hot-Spot Incr.) is a transformer-specific parameter and can generally be taken from the transformer's data sheet.

You may need to contact the manufacturer.

If manufacturer data is not available for ' H_{gr} ', use the values specified in the IEC standard.

The standard indicates that different values should be used for the hot-spot temperature ' H_{gr} ' based on the type of cooling used for medium and large power transformers.

Type of cooling	ON...	OF...	OD...
H_{gr}	26 K	22 K	29 K

A value of 23 K is suggested for distribution transformers with cooling type ONAN.

5.1.1.4 Winding exponent y

Winding exponent ' y ' is a transformer-specific parameter and can generally be taken from the transformer's data sheet.

You may need to contact the manufacturer.

If no manufacturer data is available for ' y ', it is recommended to use the values specified in the IEC standard.

The standard indicates that different values should be used for winding exponent ' y ' based on the type of cooling used for medium and large power transformers.

Type of cooling	ON...	OF...	OD...
Y (IEC 60354)	1.6	1.6	2.0
Y (IEC 60076-7)	1.3	1.3	2.0

An exponent of 1.6 is suggested for distribution transformers with cooling type ONAN.

5.1.1.5 Overview of the IEC standard settings

			Distribution transformers	Medium and large power transformers						
			ONAN	ONAN * limited oil flow	ONAN	ONAF * limited oil flow	ONAF	OFXX * limited oil flow	OFXX	ODXX
Hot spot gradient	Hgr	[K]	23	26	26	26	26	22	22	29
Winding exponent IEC 60354	y		1,6	1,6	1,6	1,6	1,6	1,6	1,6	2,0
Winding exponent IEC 60076-7	y		1,6	1,3	1,3	1,3	1,3	1,3	1,3	2,0
Constant IEC 60076-7	k ₁₁		1,0	0,5	0,5	0,5	0,5	1,0	1,0	1,0
Constant IEC 60076-7	k ₂₁		1,0	3,0	2,0	3,0	2,0	1,45	1,3	1,0
Constant IEC 60076-7	k ₂₂		2,0	2,0	2,0	2,0	2,0	1,0	1,0	1,0
Winding time constant	τw	[min]	4	10	10	7	7	7	7	7

Table 1: IEC standard settings for monitoring parameters

* The information „limited oil flow“ in the above shown table is related to the oil flow through the winding. If a winding of an ON or OF cooled transformer is zigzag-cooled, a radial spacer thickness of less than 3 mm might cause a restricted oil circulation. This fact is taken into account in the IEC 60076 algorithm.




Constants for the IEC 60076 algorithm

The constants k₁₁, k₂₁ and k₂₂ for the IEC 60076 algorithm are automatically selected by the cooling type settings. There is no need to set them manually.

5.1.2 Regulation base

Different reference temperatures can be chosen for the control of the individual fans. Because the temperature for the oil and the winding are related in terms of their formula, both temperatures can be used as base temperature.

In order to accommodate their own business philosophy, users can select which rule they use.

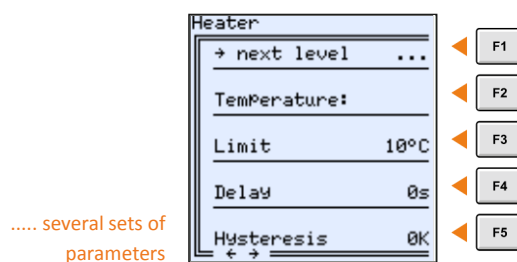
 Press <F3> in 'SETUP 1 Regulation' to choose the desired base.

The following choices are available:


- Oil (the oil temperature determines the limit values)
- Winding (the winding temperature determines the limits)
- SmrtCtrl (Smart fan control): In this operating mode, the estimated winding temperature is calculated and used to control the cooling.

5.1.3 Temperature limits


Individual limit values can be configured for each cooling stage, the heating and the oil pumps. The number of menus depends on how many cooling stages are configured and whether a cooling mode with forced circulation is selected (see the section 'SETUP 2').



The respective cooling stage is activated when the temperature exceeds the specified limit.

 Use function keys <F1...F5> to set the limit in the range of -30°C to 200°C.

 Press <Enter> to confirm the chosen limit.

 Press <F1> to access the next set of cooling stage parameters.

Time delay

To get a “balanced” operating profile for the fans the temperature must exceed the defined limit for a configurable time before it is switched on.

The switching delay can be set in the range of 0...900 s.

The sensitivity of the fans can be controlled with the help of the time delay. Short temperature increases caused by faulty transfers can be suppressed in this way.

Hysteresis

If the temperature were to fluctuate around the set limit value, it would be impossible to prevent the fan repeatedly switching on and off without specifying the hysteresis.

Since this behaviour would degrade the effectiveness of the whole system, a hysteresis in the range of a few Kelvin is recommended.

The hysteresis can be set in the range of 0...30 K.

5.1.4 Programming/Setup of the control inputs and outputs

Both the REG-D™ and the REG-DA voltage regulators can receive various control signals as binary signals and also output control signals via relay outputs.

The following Transformer Monitor specific **input functions** are available:

Input function	Description
15: BuchAlm	Buchholz alarm (indication signal)
16: BuchTrip	Buchholz trip (indication signal)
17: Oilpump1	Oil pump 1 in operation (indication signal)
79: Oilpump2	Oil pump 2 in operation (indication signal)

The 'Buchholz Alarm' and 'Buchholz Trigger' signals must be supplied to the controller by a separate Buchholz relay and can then be transmitted to a higher-level control system through a corresponding SCADA.

The following Transformer Monitor specific **output functions** are available:

The output functions are available for relays, as well as for LEDs.

Output function	Description
27: OilAlarm	Oil temperature transformer alarm
28: WndAlarm	Winding temperature alarm
29: WndTrip	Winding temperature trip
49: Heater	Heater on (control signal)
50: Cooler1	Cooling group 1 on (control signal)
51: Cooler2	Cooling group 2 on (control signal)
52: Cooler3	Cooling group 3 on (control signal)
53: Cooler4	Cooling group 4 on (control signal)
54: Cooler5	Cooling group 5 on (control signal)
55: Cooler6	Cooling group 6 on (control signal)
56: TempTC	Oil temperature tap changer alarm
57: OilvlTC-	Oil level in the tap changer to low
58: OilvlTC+	Oil level in the tap changer to high
59: OilvlTr-	Oil level in the transformer to low
60: OilvlTr+	Oil level in the transformer to high

Output function	Description
61:Water	Water in oil content, limit exceeded
62:Gas	Gas in oil content, limit exceeded
63:BuchAlm	Buchholz alarm (generated out of binary input BuchAlm)
64:BuchTrip	Buchholz trip (generated out of binary input Buchtrip)
74:OilPump	Oil pump 1 on (control signal)
80:H2	H2 in oil content, limit exceeded
81:CO	CO in oil content, limit exceeded
84:OilPump2	Oil pump 1 on (control signal)

A specific control function (e.g. 'Oil pump' or 'Fan group') is assigned to a specific relay output in the Controller menu.

The configuration process is described using examples.

The assignment of a specific control function (e.g. oil pump or fan group) to a particular relay output must be carried out using the Relay Assignment function on the regulator menu.

Setup can be done very comfortable using the WinREG (in future AE Toolbox) software.

The setup procedure of a few relay outputs using combinations of front panel keys on the regulator is described below.

Example:

To program the regulator as follows:

- The Oil pump should be controlled by relay output 8 on the REG-DA.
- Fan group 1 via the output relay 9
- Fan group 2 via output relay 10
- Fan group 3 via the output relay 11.

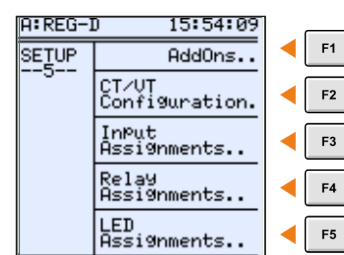
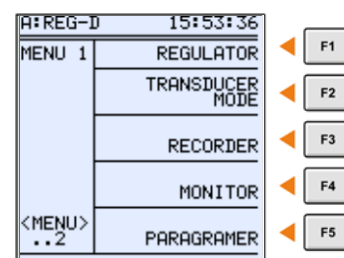
To do this, press <MENU> repeatedly until you reach the main menu of the regulator.

Press the menu key or the arrow buttons <,> until you reach Setup 5.

In SETUP 5, select the "Relay assignments" using the F4 function button.

Press the <F1> button to display the relay outputs

Rel 5 ... Rel 8. Press <F5> to assign the "oil pump" output function to relay 8. To do this use the function buttons F1, F2, F4, F5 to select output function 74: OilPump, and confirm the selection by pressing enter.



The oil pump is now permanently assigned to relay output 8.

Proceed in the same manner for output relays 9, 10 and 11.

Please note that fan groups 1, 2 and 3 are only permanently assigned to the specified relay outputs when “fixed” is selected in the fan assignment menu. If the fans are cyclically controlled, the assignment alters according to the individual fan running times.

The setup of the input functions is carried out in the same way by using SETUP 5 of the menu.



Setup of the binary in- and outputs

Additional Information regarding the binary in- and outputs and the according setup can be found in the manual of the REG-D(A).

5.2 Analog Channels

5.2.1 Analog in- and outputs

The physical quantities of temperature (transformer, tap changer) or oil level (transformer, tap changer), water contents, gas in oil etc. can be input to the regulator as mA signals.

Each REG-DTM regulator can be equipped with up to three analogue modules, each of which can in turn be equipped with either two analogue inputs or two analogue outputs.

The REG-DA can have up to eight analogue inputs and up to seven analogue outputs. However, the number of channels required must be specified at the time of ordering, since changes to the equipment later are not possible in the field.

The analogue modules can be positioned on any of the available slots on the REG-CPU card of the REG-DTM (refer page 42). The regulator automatically detects the type of equipment and adaptively displays the corresponding menus.

The setup of analogue inputs and outputs can be carried out simply using WinREG (in future AE Toolbox) software. In principle, all setups can be carried out using the front panel keys. For more information about this, please refer to the REG-DTM or REG-DA operating manuals.

The following Transformer Monitor specific **input functions** are available:

Input function	Description
64:iOilTp-TR	Oil temperature of the transformer
65:iOilTp-TC	Oil temperature of the tap changer
66:iOilL-TR	Oil level of the transformer
67:iOilL-TC	Oil level of the tap changer
68:iWater	Water in oil content (moisture in oil)
69:iGas	Gas in oil content
71:iCO	CO in oil content
72:iH2	H2 on oil content
73:iWndTp-TR	Winding temperature transformer (directly measured by e.g. a fibre optic temperature measurement device like the REG-FO)

The following Transformer Monitor specific **output functions** are available:

Output function	Description
19:oOilTp-TR	Oil temperature of the transformer
20:oWindTemp	Winding temperature



Analogue channel function 01:ANA

The input function 01:ANA is always selected when a non-standard measured quantity is used.

In principle, any arbitrary measured quantity that can be represented as a mA value can be fed into the controller, processed and displayed.

If necessary, limit values can of course be derived from such 'non-standard inputs' and output by relay. To do this, please contact the A. Eberle head office by using +49(0)911/628108-101 or regsys-support@a-eberle.de.

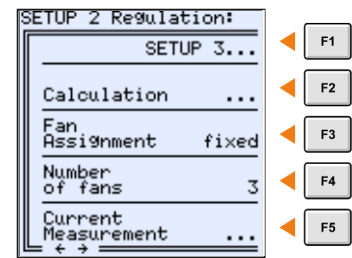


Setup of the analogue channels

Additional Information regarding the analogue channels and the according setup can be found in the manual of the REG-D(A).

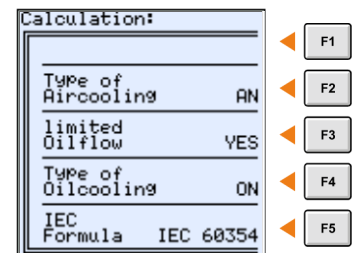
5.3 SETUP 2: Regulation

- ✎ SETUP 2 is accessed by pressing the '→' arrow or <F1> in 'SETUP 1'.



5.3.1 Calculation

- ✎ By pressing the <F2> button the menu Calculation settings are reached. Here you are able to set the type of cooling and the IEC algorithm that is used for determining the Hot spot temperature.



Type of air cooling (outer cooling medium)

The following options are available:

- AN: Stands for Air Natural, meaning that the transformer does not have any fans and that air is moved by convection.
- AF: Stands for Air Forced, meaning that the transformer has fans

Limited oil flow

The following options are available:

- Yes
- No

This parameter is used in accordance with IEC 60076. It takes into account that the transformer has a limited oil flow by design (see also chapter 5.1.1.5). The manufacturer can tell you if the transformer has a limited oil flow as described in the IEC standard.



Setup the parameter „Limited oil flow“ without knowing the winding design

If now information about the winding design is available the setting „YES“ for the “limited oil flow” parameter is recommended. This setting will lead during a load increase to a higher estimated Hot-Spot Temperature which is the safer variant.

Type of oil cooling (inner cooling medium)

The following options are available:

- ON: Stands for ONAN or ONAF cooling
- OF: Stands for OFAF or OFWF cooling
- OD: Stands for ODAF or ODWF cooling
- ON/OF: Stands for switching between ON and OF cooling. In this case, at least one controllable oil pump is available:
- ON/OD: Stands for switching between ON and OD cooling. In this case, one device to steer the oil and at least one controllable oil pump are available.

The 'Transformer parameters' and 'Temperature limits' menus each have two additional parameter tabs for the oil pumps when cooling modes ON/OF and ON/OD are activated.

IEC Formula

The following options are available:

- IEC 60354
- IEC 60076

The parameter determines the algorithm used to calculate the hot-spot temperature.

5.3.2 Fan assignment

To enable users to assign a specific fan to a cooling stage or let the system decide which fan to activate for a cooling stage, the Transformer Monitor offers the choice between:

- fixed

and

- cyclical

If the parameter 'fixed' is chosen the fans are assigned to a specific cooling stage, fan 1 will always be switched on for cooling stage 1. Over a long period of operation, this setting will result in a high operating time and thus wear of fan 1, whereas that of the higher cooling stages will be very small.

If 'cyclical' is chosen for the fan assignment, the controller decides which fan is switched on in proportion to the total operating time of each cooling stage. Over the service life, this algorithm achieves a more or less equal operating time for all fans.

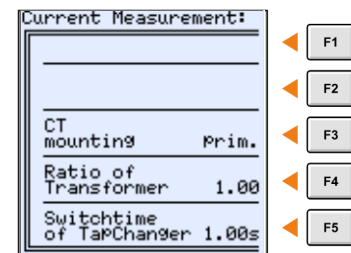
5.3.3 Number of fans

As the number of fan groups varies by transformer type, the current number can be entered in the menu. As a result, this setting will be adjusted in all menus in which fan control and fan service life parameters are configured.

There are a total of six fan cooling groups that are identified in the menu by the numbers 1: to 6:.

5.3.4 Current measurement

A transformer's hot spot is affected by a number of transformer parameters (Hgr, Y, time constant) and by the two measured quantities oil temperature and current through the winding. Different sources to measure the current are available for different applications. The necessary settings can be made in the 'Current Measurement' setup.



5.3.4.1 CT mounting

The "CT mounting" submenu can be used to specify where the current is measured from. If "Secondary" is chosen, the current that is connected to the first current measurement input is used for the calculation. If "primary" is selected, the current at the second current measurement input is selected. "Primary" can only be used if the "three winding" feature is activated with hardware characteristic M9. Furthermore, the current required to calculate the hot-spot temperature can be supplied via an analogue mA input. If this option is required, please contact A. Eberle GmbH & Co. KG.

5.3.4.2 Ratio of the power transformer

In order to determine the primary current when measuring the secondary current, the power transformer's conversion ratio is used to convert the measured current to primary current. This parameter is also used to calculate the secondary current for the Monitor's 'Windings' screen when the primary current is measured. This setting is only necessary if the current measurement is taken from the secondary side of the power transformer.

5.3.4.3 Tap changer switching time

The value I^2t is used to record the quality of the contact load in the tap changer. The current used to calculate I^2t is taken from the continuous measurement of the current, while the switching quantity 't' is a tap-changer specific value.

If detailed information about the tap changer is not available, sufficiently good results will be achieved with a switching time in the range of 0.02 to 0.06 s.

✎ Press <F5> to enter the switching time for the tap changer.

✎ Press <Enter> to confirm the entry.

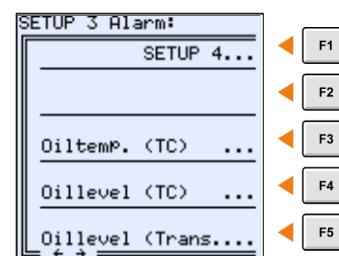
5.4 SETUP 3: Alarm

✎ SETUP 3 is accessed by pressing the '→' arrow or <F1> in SETUP 2.

Use <F2...F5> to access other submenus in which limits, switching delays and hysteresis can be selected.

Since the logic of the submenus is the same, the description of the individual screens is short. However, the hardware requirements must be met so that the controller can receive the measured quantities, which are usually supplied by external transducers as mA signals.

The total number of analogue channels (order characteristics E + C) can be expanded at any time with analogue interface cards (ANA-D) (see chapter 7 'Increasing the system's hardware resources').



5.4.1 Oil temperature (TC)

Oiltemp.(TC)	
	F1
	F2
Max	70°C
Delay	0s
Hysteresis	1K
	F5

5.4.1.1 Maximum value

Defines the switch-on point for the alarm signal.

Setting range: 0...150°C

5.4.1.2 Switching delay

Defines the switch-on delay for the alarm signal.

Setting range: 0...900 s

5.4.1.3 Hysteresis

Defines the hysteresis for the switching point.

Setting range: 1...30 K

5.4.2 Oil level (TC)

Oillevel(TC)	
	F1
Min	95%
Max	105%
Delay	0s
Hysteresis	1%
	F5

Minimum value

Defines the switch-on point for the 'Oil level too low' alarm signal.

Setting range: 0 ... 150%

Maximum value

Defines the switch-on point for the 'Oil level too high' alarm signal.

Setting range: 0 ... 150%

Switching delay

Defines the switch-on delay for the alarm signal.

Setting range: 0...900 s

Hysteresis

Defines the hysteresis for both switching points.

Setting range: 1 ... 30%

5.4.3 Oil level (transformer)

Oillevel(Trans.)	
Min	95%
Max	105%
Delay	0s
Hysteresis	1%

F1

F2

F3

F4

F5

Minimum value

Defines the switch-on point for the 'Oil level too low' alarm signal.

Setting range: 0 ... 150%

Maximum value

Defines the switch-on point for the 'Oil level too high' alarm signal.

Setting range: 0 ... 150%

Switching delay

Defines the switch-on delay for the alarm signal.


Setting range: 0...900 s

Hysteresis

Defines the hysteresis for both switching points.

Setting range: 1 ... 30%

5.5 SETUP 4: Alarm

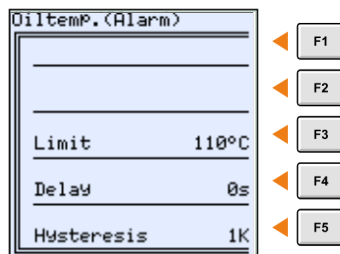
 SETUP 4 is accessed by pressing the '→' arrow or <F1> in SETUP 3.

Use <F2...F5> to access other submenus in which limits, switching delays and hysteresis can be selected.

In setup 4 the limits for oil temperature alarm, winding temperature alarm and the winding temperature trip can be adjusted.



5.5.1 Oil temperature (Alarm)



Limit value

Defines the switch-on point for the alarm signal.

Setting range: 0...150°C

Switching delay

Defines the switch-on delay for the alarm signal.

Setting range: 0...900 s

Hysteresis

Defines the hysteresis for the switching point.

Setting range: 1...30 K

5.5.2 Winding temperature (Alarm)

Windingtemp. (Alarm)	
	F1
	F2
Limit 120°C	F3
Delay 0s	F4
Hysteresis 1K	F5

Limit value

Defines the switch-on point for the alarm signal.

Setting range: 0...200°C

Switching delay

Defines the switch-on delay for the alarm signal.

Setting range: 0...900 s

Hysteresis

Defines the hysteresis for the switching point.

Setting range: 1...30 K

5.5.3 Winding temperature (Trip)

Windingtemp. (Trip)	
	F1
	F2
Limit 130°C	F3
Delay 0s	F4
Hysteresis 1K	F5

Limit value

Defines the switch-on point for the alarm signal.

Setting range: 0...200°C

Switching delay

Defines the switch-on delay for the alarm signal.


Setting range: 0...900 s

Hysteresis

Defines the hysteresis for the switching point.

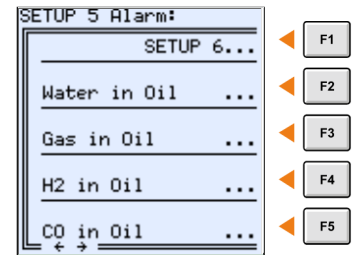
Setting range: 1...30 K

5.6 SETUP 5: Alarm Water and Gas in oil

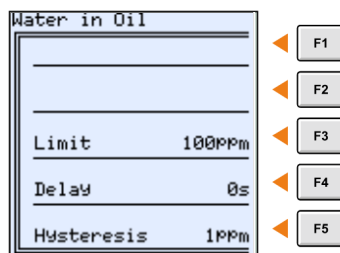
 SETUP 5 is accessed by pressing the '→' arrow or <F1> in SETUP 4.

Use <F2...F5> to access other submenus in which limits, switching delays and hysteresis can be selected.

In the setup 5 the parameters of the limits water in Oil, gas in oil, H2 in oil and CO in oil can be set.



5.6.1 Water in Oil content



Limit value

Defines the switch-on point for the alarm signal.

Setting range: 0...1000000 ppm

Switching delay

Defines the switch-on delay for the alarm signal.

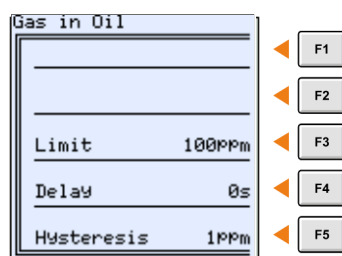
Setting range: 0...900 s

Hysteresis

Defines the hysteresis for the switching point.

Setting range: 1...100000 ppm

5.6.2 Gas in Oil (Total gas in Oil) content



Limit value

Defines the switch-on point for the alarm signal.

Setting range: 0...1000000 ppm

Switching delay

Defines the switch-on delay for the alarm signal.

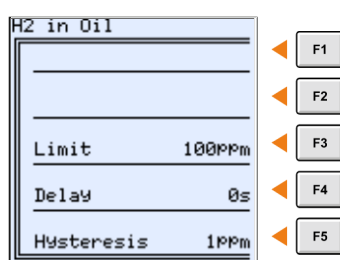
Setting range: 0...900 s

Hysteresis

Defines the hysteresis for the switching point.

Setting range: 1...100000 ppm

5.6.3 H2 (Hydrogen) in Oil content



Limit value

Defines the switch-on point for the alarm signal.

Setting range: 0...1000000 ppm

Switching delay

Defines the switch-on delay for the alarm signal.

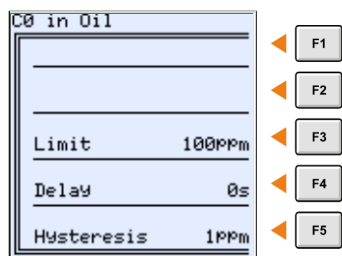
Setting range: 0...900 s

Hysteresis

Defines the hysteresis for the switching point.

Setting range: 1...100000 ppm

5.6.4 CO (Carbon Monoxide) in Oil content



Limit value

Defines the switch-on point for the alarm signal.

Setting range: 0...1000000 ppm

Switching delay

Defines the switch-on delay for the alarm signal.


Setting range: 0...900 s

Hysteresis

Defines the hysteresis for the switching point.

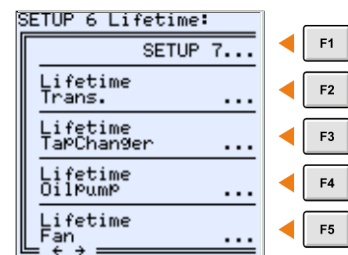
Setting range: 1...100000 ppm

5.7 SETUP 6: Lifetime

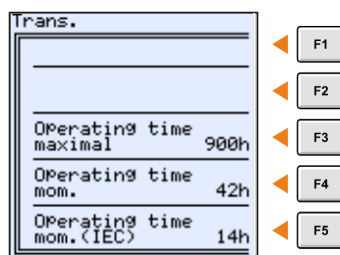
 SETUP 6 is accessed by pressing the '→' arrow or <F1> in SETUP 5.

The maximum service life and the currently elapsed operating hours for the different equipment are entered in the 'Service life' submenu. This must be done when the monitoring system is installed on a transformer that is already in service.

This menu can also be used to set the 'Service life' parameter when individual devices are replaced.



5.7.1 Lifetime Transformer



Operating time maximal

Press <F3> to enter the expected maximum service life (see the manufacturer's data).

Setting range: 0...999999 h

Operating time mom.

This is where the current operating hours for the transformer (see the section 'Operating hours (1)') are adjusted. This setting is important if the system is not installed at the same time as the transformer. Adjustments may also need to be made in conjunction with revisions.

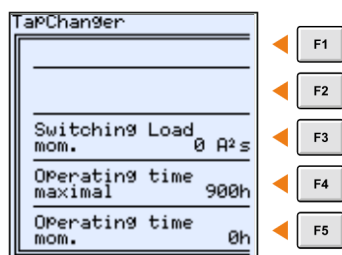
Setting range: 0...999999 h

Operating time mom. (IEC)

This is where the IEC-based operating hours (loss of life) are adjusted.

Setting range: 0...999999 h

5.7.2 Lifetime Tap changer



Switching load

This is where the current switching load for the tap changer is adjusted.

Setting range: 0...9000000 A²s

Operating time maximal

Press <F4> to enter the expected maximum service life (see the manufacturer's data).

Setting range: 0...999999 h

Operating time mom.

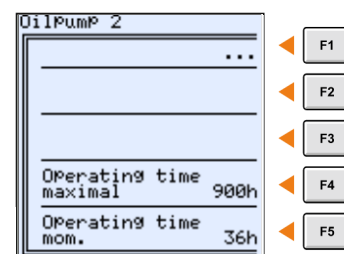
The 'Current operating hours' parameter is important if the system is not installed at the same time as the tap changer. Both parameters may need to be adjusted in conjunction with revisions.

Setting range: 0...999999 h

5.7.3 Lifetime Oil pump

After entering the menu there are the settings for oil pump one shown. The values for oil pump two can be reached by pressing the <F1> button.

..... several sets of values



Operating time maximal

Press <F4> to enter the expected maximum service life (see the manufacturer's data) for the oil pumps.

Setting range: 0...999999 h

Operating time mom.

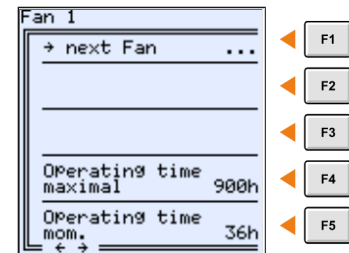
The 'Elapsed operating hours' parameter is important if the system is not installed at the same time as the transformer and the oil pump. Both parameters may need to be adjusted in conjunction with revisions.

Setting range: 0...999999 h

5.7.4 Lifetime Fan

The number of parameter/value sets is based on the number of fans used. To change between the different fans press the <F1> button or use the arrow left and right keys.

..... several sets of values



Operating time maximal

The 'Elapsed operating hours' parameter is important if the system is not installed at the same time as the transformer and the fan groups. Both parameters may need to be adjusted in conjunction with revisions of the fans.


Setting range: 0...999999 h

Operating time mom.

Press <F5> to enter the current age of the fans.

Setting range: 0...999999 h

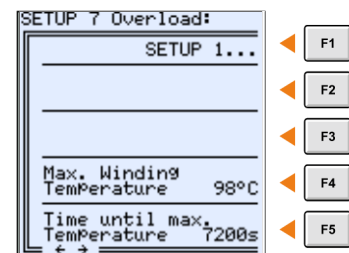
5.8 SETUP 7: Overload

 SETUP 7 is accessed by pressing the '→' arrow or <F1> in SETUP 6.

The overload parameters are set in Setup 7.

5.8.1 Max. Winding temperature

The parameter 'Max. winding temperature' specifies the limit value for the winding temperature used to calculate the 'permissible overload' and the 'Time to Overtemp.' The default value is 98°C. The parameter range is from -30 to 200 °C.



5.8.2 Time to max. temperature

The parameter 'Time to max. temperature' specifies the time window for the 'permissible overload'. For example, a setting of 7200 s means that the 'permissible overload' is calculated so that the maximum winding temperature is reached after 2 h = 7200 s. The parameter range is 1 to 7200 seconds.

6. Retrofit of analogue channels (only REG-D™ and TMM)



Check the wiring

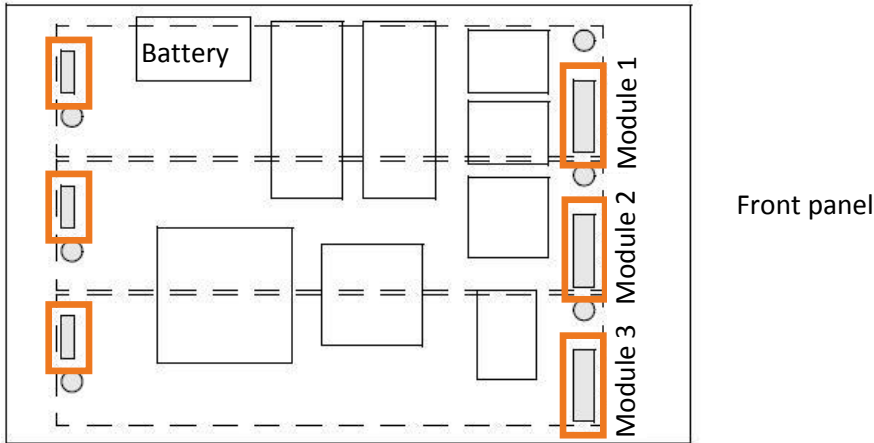
Please check first whether the housing/rack has the wiring for the analogue channels. If this is not the case, a rewiring has to be done. It is recommended that this work be carried out at the A. Eberle REGSys™ support team (regsys-support@eberle.de, +49(0)911/628108-101). On the same occasion, retrofitting of the analogue channels in the REG-D™ can also take place.

If the housing/rack already has wiring for analogue channels, the analogue channels can be upgraded based on the following description.

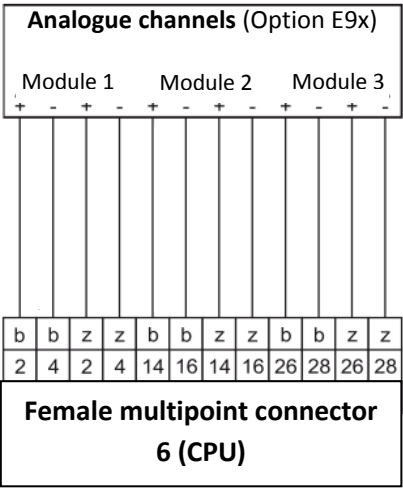
The REG-D™ has a total of three slots for analogue modules.

Numbering of the slots is always from top to bottom. That is, the first module (upper), is recognized by the firmware as channel 1 and 2. The middle slot accepts channels 3 and 4, and the lowest slot channels 5 and 6.

Location of analogue slots on the REG-CPU processor board:



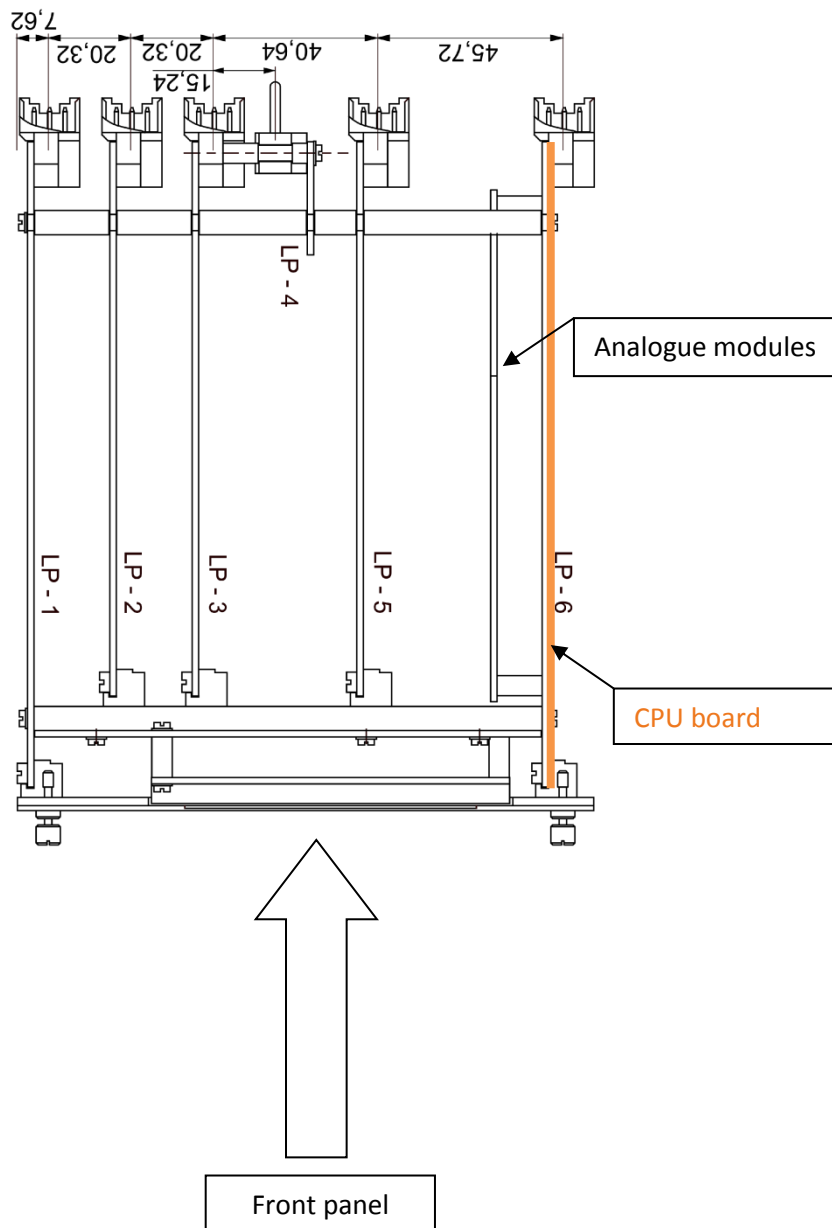
The red rectangles indicate the location of the connector between the CPU and the analogue modules.



- Module 1.1 - Channel 1
- Module 1.2 - Channel 2
- Module 2.1 - Channel 3
- Module 2.2 - Channel 4
- Module 3.1 - Channel 5

For retrofitting of analogue modules it is necessary to remove the REG-D™ from the housing. To do so, loosen the four retaining screws and pull the REG-D™ out with aid of the removal tool. Now place the REG-D™ in front of you on a work surface. To ensure correct channel assignment of the analogue channels, insert the REG-D™ in the correct direction on the pad. That is, so you can read the indicator plates. The individual printed circuit boards are then placed vertically.

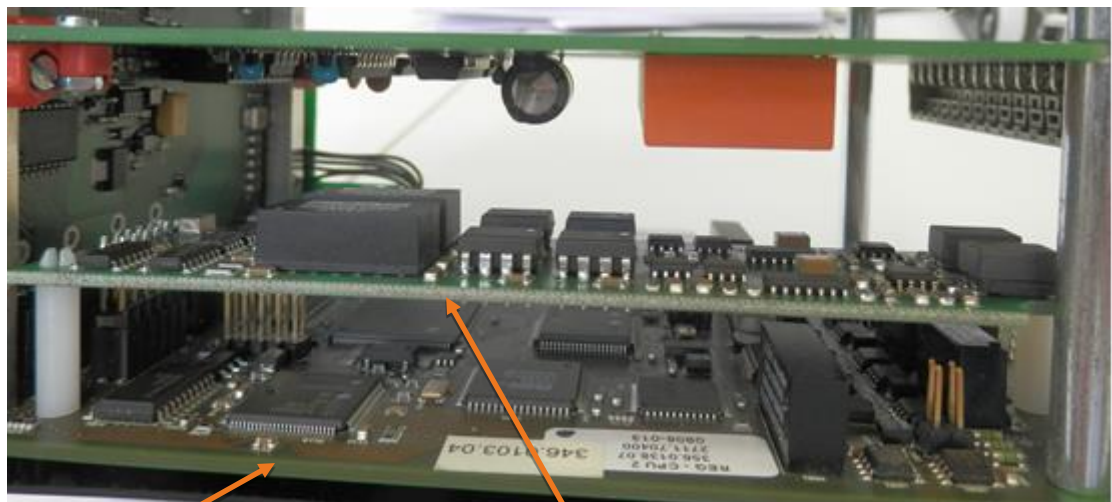
The analogue modules are plugged on the CPU board, which is located on the far right as seen from the front over the display.



The analogue modules themselves are plugged into the corresponding socket on the CPU board. Please ensure correct placement of all connectors.

We take care of it.

In addition to the connectors, the modules are also connected to the CPU board with two pluggable plastic spacers. Please also note correct placement here.



CPU board

Analogue module
(slot 1, occupied)

After plugging the analogue modules, the REG-D™ can be reinserted into the housing.

The analogue channels are automatically detected by the firmware after you restart the device, and can then be configured via the menu "Setup -6-\General\Analog..", or the configuration software WinREG (in future AE Toolbox).

Please note that the analogue channels can only be used directly as of firmware version 2.00. With older firmware versions, a background program is necessary.

For questions regarding this matter, please contact the A. Eberle REGSys™ support team (regsys-support@a-eberle.de, +49(0)911/628108-101).

7. Increasing the system's hardware resources

To increase the number of channels, multiple interface cards can be connected on the COM 3 (RS485) peripheral interface. Interface cards are available for analogue inputs and outputs (ANA-D) as well as for binary inputs and outputs (BIN-D). It is also possible to communicate directly with other devices through the COM3/Modbus converter.

7.1 Additional inputs and outputs

The ANA-D interface card can be supplied with either eight analogue inputs or eight analogue outputs. It is not possible to combine inputs and outputs on one card.

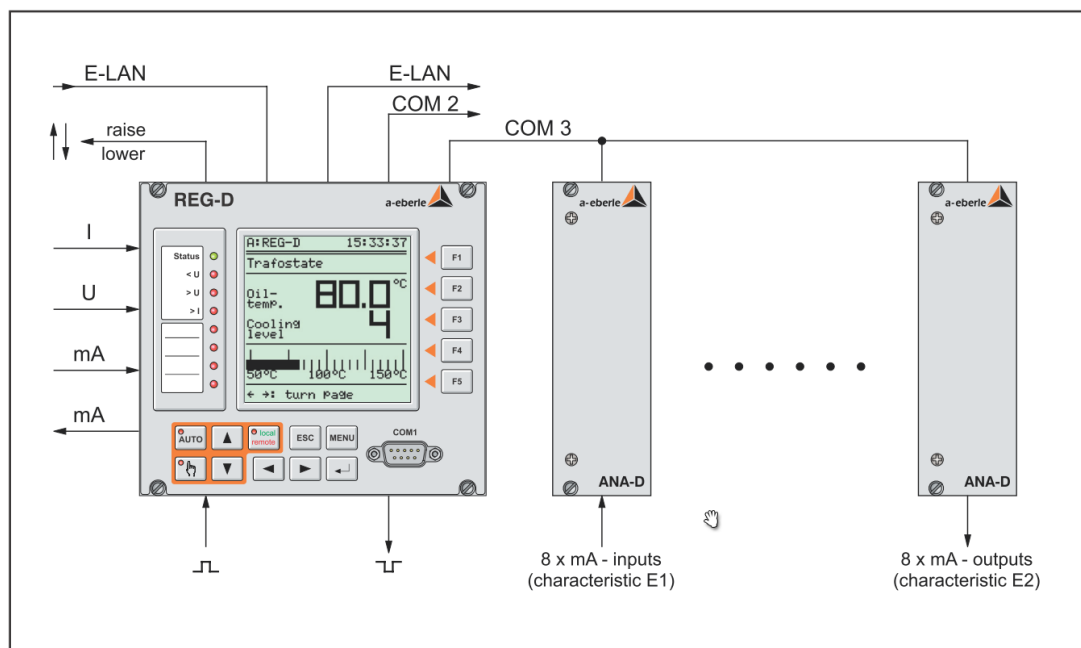


Figure 9: Hardware extension via ANA-D

The BIN-D interface card can be supplied with either eight relay outputs or sixteen optically decoupled binary inputs.

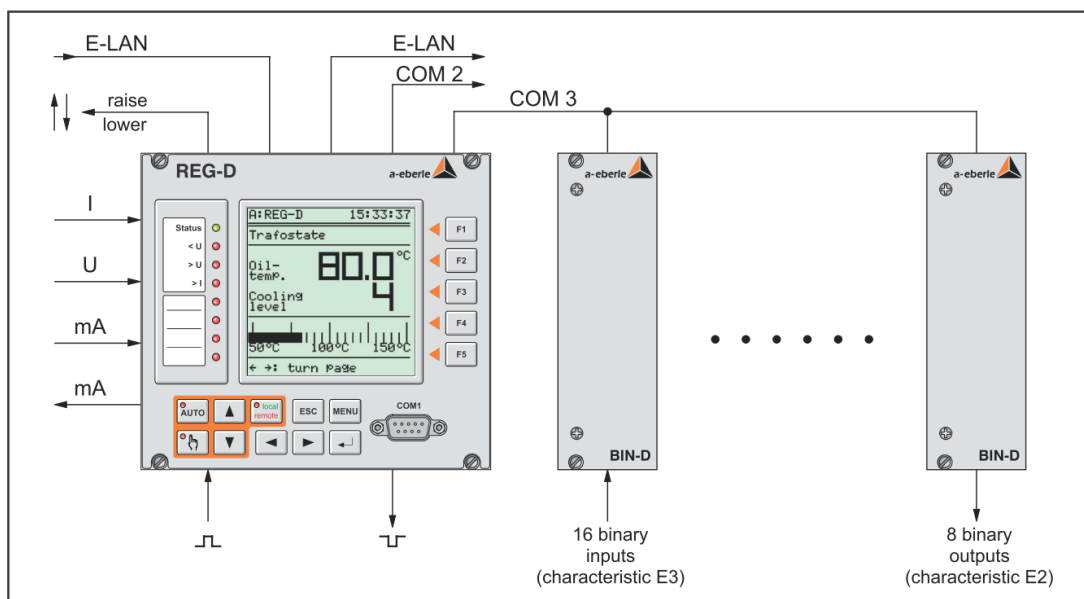


Figure 10: Hardware extension via BIN-D

ANA-D and BIN-D interface cards can be combined on COM3 as desired.

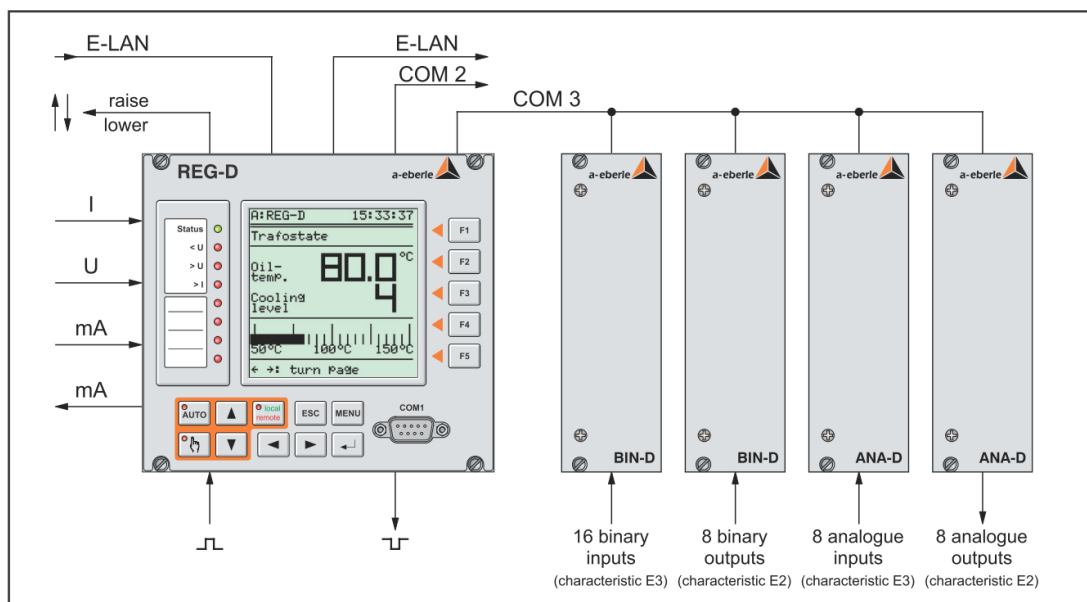
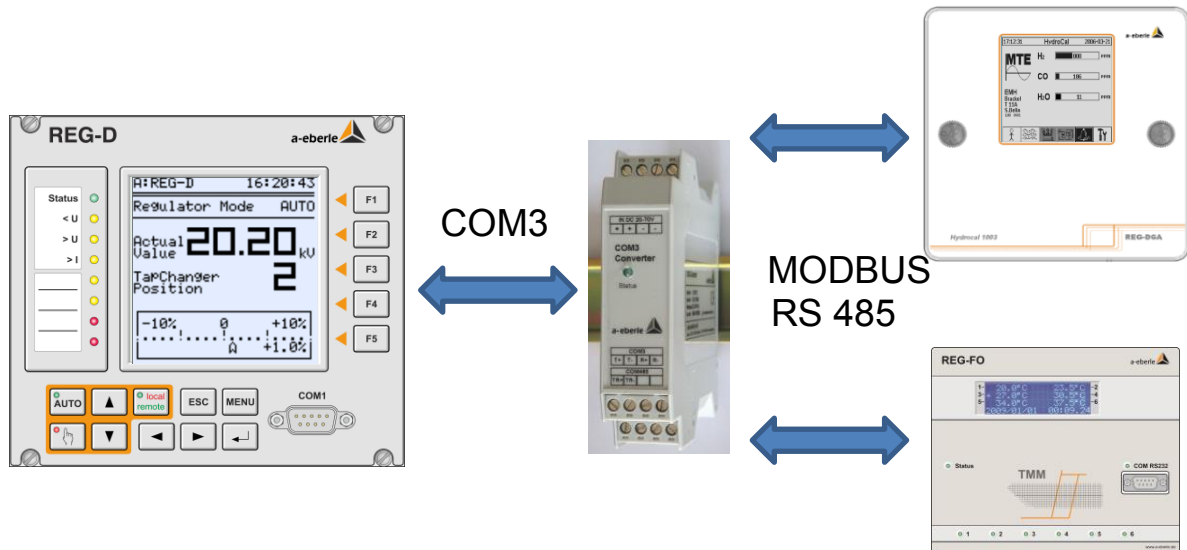


Figure 11: Hardware extension via ANA-D and BIN-D

7.2 COM3/Modbus (RTU Master) Converter

The COM3/Modbus converter enables serial communication with any sensor or device that supports the Modbus RTU protocol (slave). This enables temperature, gas in oil and ambient measurements to be directly recorded and processed. Conversion to a mA-Signal is no longer necessary. The recorded data can be used and recorded for monitoring, and of course transferred to the SCADA system.



8. Temperature measurement

As described earlier, there are two ways of measuring the oil temperature:

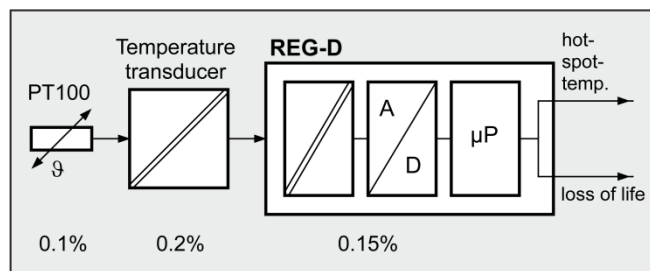
- The temperature signal is supplied by a temperature transducer as a 4...20 mA signal.
- The temperature signal is supplied by a PT-100 sensor in a three-wire circuit.

8.1 Accuracy considerations

From a measurement standpoint, the accuracy of the hot-spot temperature recording is essentially influenced by the oil temperature measurement.

Calculating the hot-spot temperature from the measured oil temperature does not introduce any additional errors.

The measuring chain:



Error determination:

Assuming that the error in the resistance thermometer PT100 in temperature range 20 to 140°C does not exceed 0.1%, the average total error is achieved when using the proposed temperature transducer:

$$F_m = \sqrt{0,1\%^2 + 0,2\%^2 + 0,15\%^2}$$

The average error is:

$$F_m = 0,26 \%$$

The maximum error is, however:

$$F_{max} = 0,10 \% + 0,20 \% + 0,15 \%$$

$$F_{max} = 0,45 \%$$

In the case of the built-in PT100 module, the average error is:

- the average error is: 0.13 %
- and the maximum error is: 0.35 %



Note:

All errors are relative to the measurement range max. value.

9. Warranty

The guarantee period for the REG-D(A) voltage regulator covers 3 years. If the regulator is modified in a non-authorised place, no claims will be accepted.

However, if the regulator is returned to A. Eberle for modification, the guarantee remains intact.

10. Test report

A test report of the “Measuring the hot-spot temperature” and “Determining the reduction in lifetime” basic functions is available at A. Eberle GmbH & Co.KG. If you are interested in this test report please contact the REGSys™ support team (regsys-support@a-eberle.de, +49(0)911/628108-101).

Notes

[illegible]

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