a-eberle

Operating instructions

Digital
Transformer Monitoring System

GB

REG-DM

Table of Contents

1. Basic information about 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 take its "temperature curve" (the thermal image) so as to collect information about the current load and the expected remaining life. This task can - based on IEC standards - be solved by electronic measuring and computing facilities.

This manual describes the main functions and the various steps for operation of the transformer monitoring.

To determine the winding hot spot temperature, in addition to the current through the windings, the oil temperature is an important parameter. The oil temperature can be supplied by the REG-DM as either a mA signal or directly as a PT 100 signal. Appropriate input modules are available for both forms of signal. If, in addition, the fluid levels and other variables such as the moisture, H2 and CO content of the oil are also to be recorded, corresponding analogue input channels must be present, which can be retrofitted to the REG-DM at any time.

With monitoring, the essential parameters of the transformer are monitored. In addition to the tap-changer statistics and the current, the oil temperature is recorded. The hot spot temperature is determined and the lifetime consumption of the transformer calculated in accordance with: CEI/IEC 354:1991. VDE-0536/3.77 applies as the German equivalent of IEC 60354. Depending on the winding temperature, up to six cooling stages can be activated. 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 certain cooling stage. Additional alarms such as Buchholz warning and/or Buchholz triggering can be supplied as digital signals to the controller, display and to a SCADA system for further processing (see Figure 1).

The following protocols are available for transmission to process control equipment:

- IEC 60870-5-101
- IEC 60870-5-103
- IEC 60870-5-104
- DNP 3.0
- IEC 61850
- LON
- MODBUS
- PROFIBUS
- SPABUS

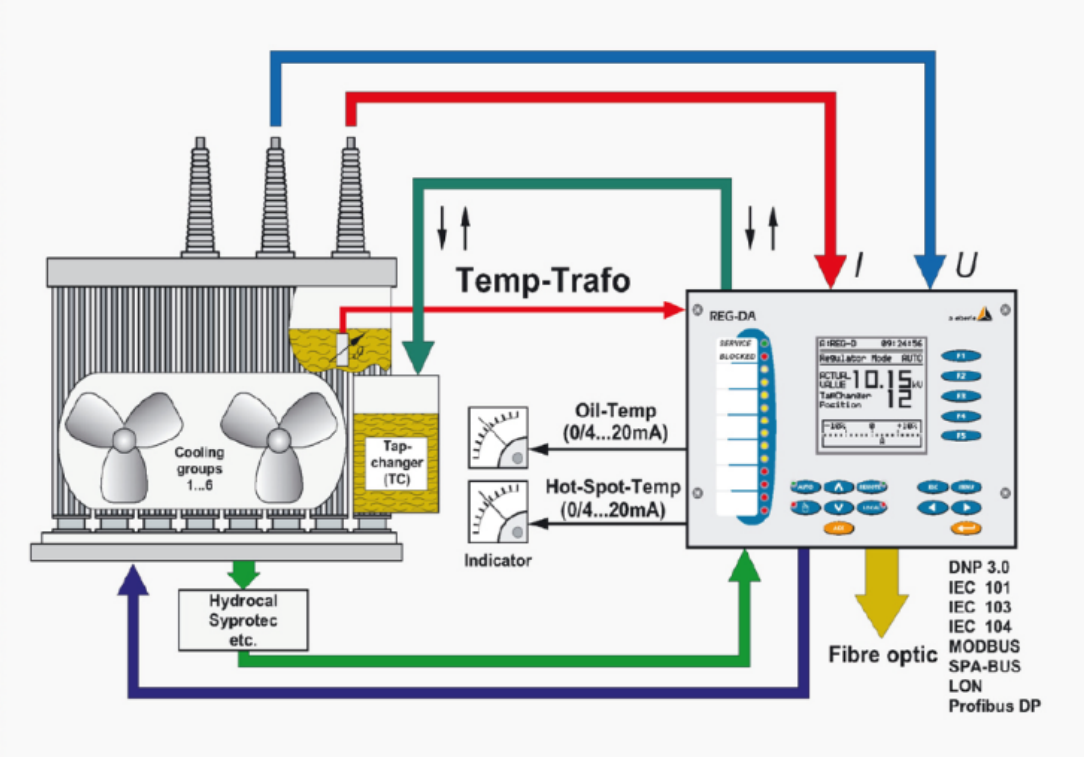


Figure 1

The thermal situation in the transformer can be represented graphically (see Figure 1), where this is a simplified view of a complex situation. The following simplifications are necessary:

- it is assumed that the oil temperature in the tank increased linearly from the bottom to the top
- another assumption is that the average temperature of the winding is also linearly parallel to the oil temperature with a constant temperature differential g_r increasing from the bottom to the top
- it is assumed that the hot spot temperature (P) is higher than the temperature of the winding (hot) at the upper end of the winding. The increase in temperature between the hot spot in the winding and the oil temperature in the tank is designated as a constant Hg_r (hot spot at top oil gradient). Studies have been able to prove that the factor H, depending on the transformer size, short-circuit impedance and winding design, can vary between 1.0 and 2.1.

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

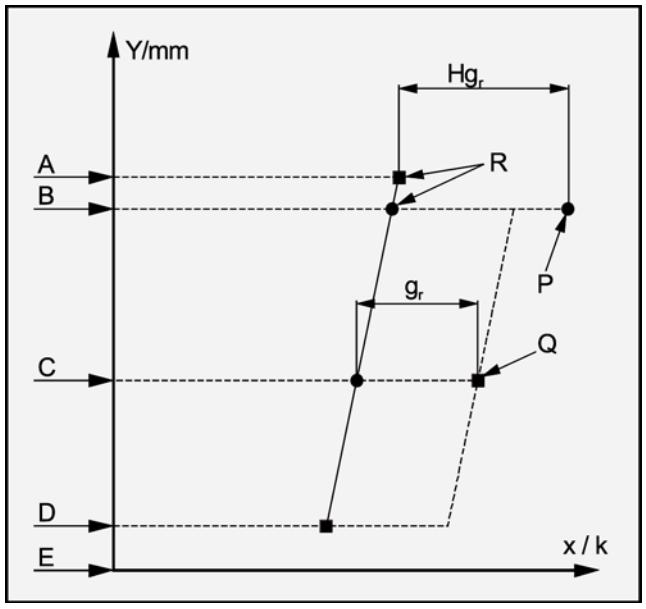


Figure 2

A Temperature of the upper layer of oil
B Temperature in the transformer tank at the upper end of the winding
C Temperature of the oil filling of the tank 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

In the basic version only one current input is available for determining the hot spot temperature. The measurement of the three currents via an Aron circuit is also possible as additional equipment.

In most cases, this interpretation will lead to sufficiently good results, because it may be assumed that the transformer is loaded approximately uniformly.

For this general operation case: $I1 \sim I2 \sim I3$

The calculation of the hot point or hot-spot temperature and the control of cooling equipment is based on the model shown in Figure 3.

Next to the operating current, the oil temperature is the most important process variable for the estimation and calculation of the hot-point and hot-spot temperature Θ_h. Wit the REG-DM, up to three oil temperatures can be recorded and used for calculation. Each measured oil temperatures, in conjunction with the current and the characteristics of the transformer is fed into the equation in order to obtain a thermal image of the transformer. On this basis, in addition to the hot-spot temperatures, the life consumption of the insulation can also be calculated.

To control the temperature of the transformer, a six-stage fan, an oil pump and a heater can be switched. Control of the fan can be manual (HAND) or automatic (AUTO). If the fan is to be switched manually, this is done in the REG-DM's HAND mode using the "Up Arrow" and "Down Arrow" buttons. Which outputs are used to control the fan and through which inputs the temperature signals are fed to the controller can be set up later using the menu-driven configuration.

As standard, a configurations is supplied in which only a few details have to be changed occasionally. If additional analogue inputs or outputs and/or additional digital inputs or outputs are required, in the case of the REG-DM, interface modules (ANA-D and BIN-D) can be connected via the COM 3 of the controller. In this way, the hardware resources of the basic unit can be increased.

If the information provided by the system is properly utilized, with the help of the function with a comparatively low use of resources, the availability of the transformer can be increased significantly.

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

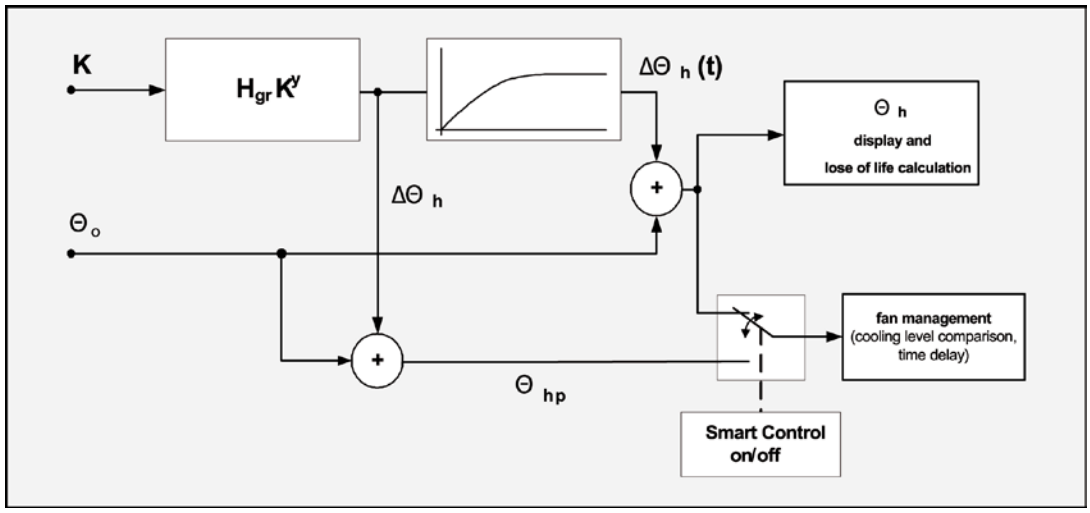


Figure 3

K : Load factor = I / I_N
Θ_0 : Oil temperature (measured)
Hg_r : 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

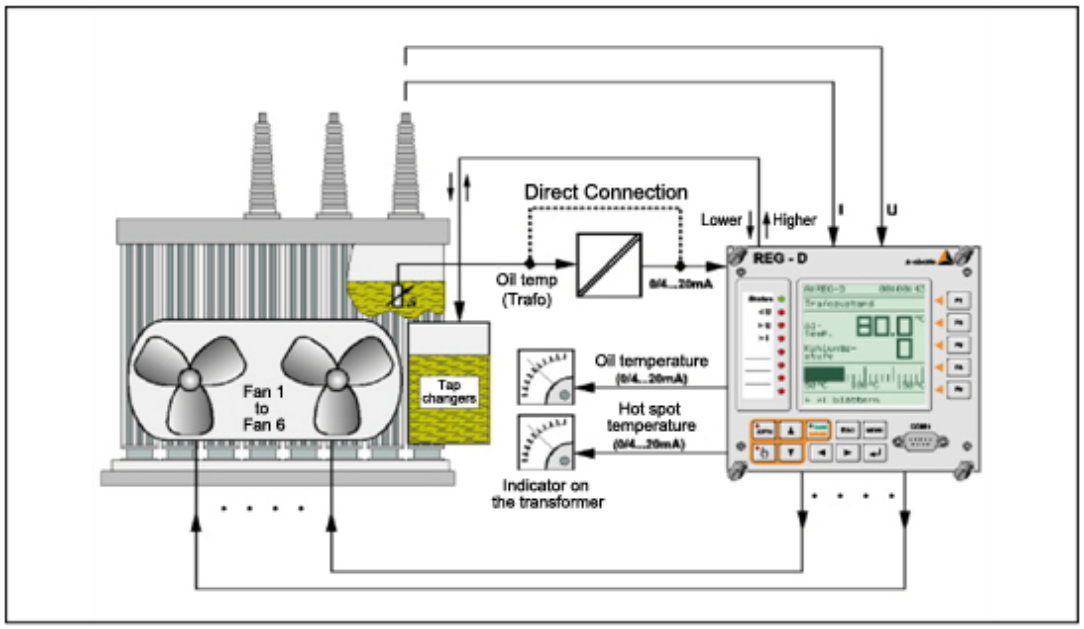


Figure 4

If there is already a temperature transmitter available for recording the oil temperature, the oil temperature can be supplied to the controller as a mA input. If necessary, the temperature sensors can also be connected directly in 3-wire circuit.

If remote temperature readings are to be controlled, both the hot-spot temperature and the oil temperature can be provided as a mA output.

As a function of the oil or hot-spot temperature, up to six groups of fans, an oil pump and a heater can be switched.

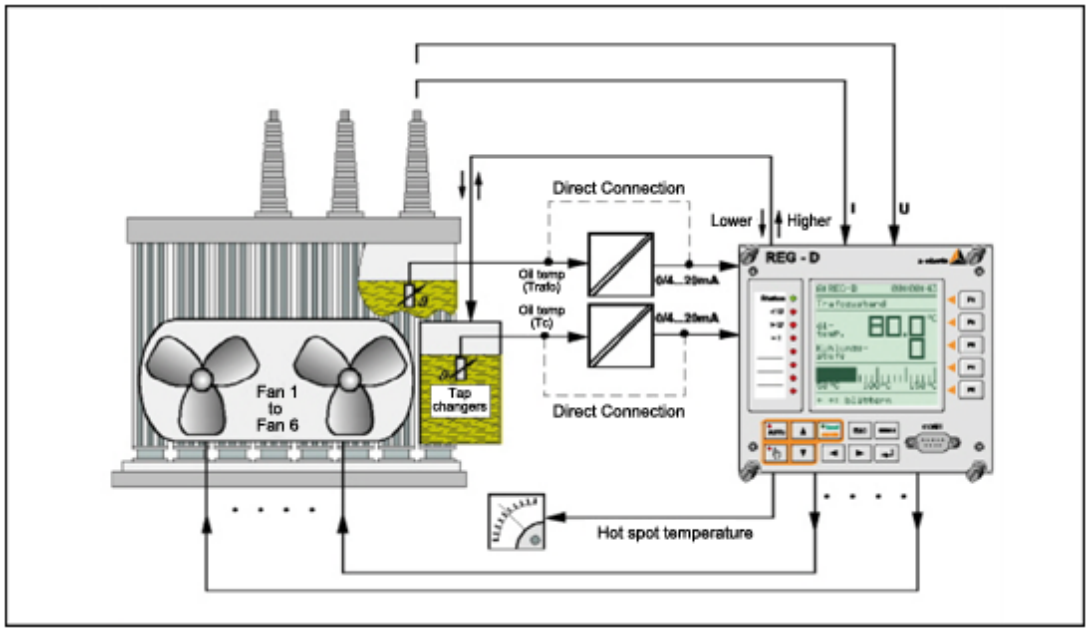


Figure 5

Should the oil temperature also be recorded in the tap vessel, a second mA or PT 100 input must be available.

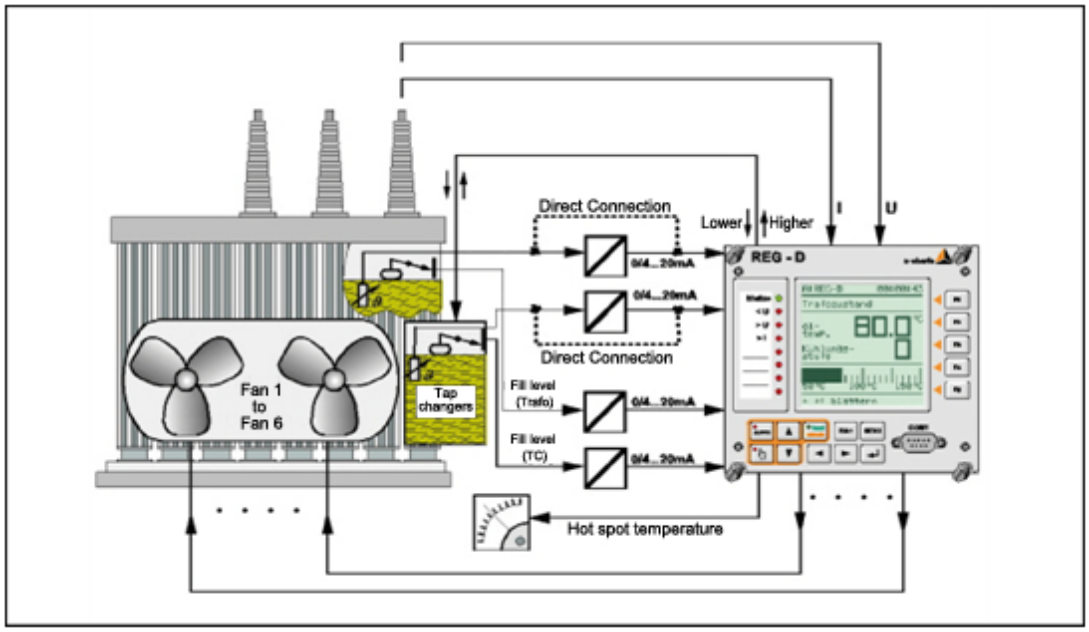
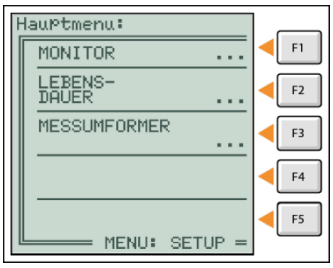


Figure 6

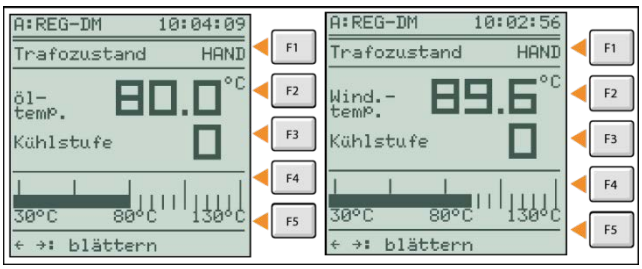
In addition, the levels of the transformer and/or tap changers can be recorded and fed to the controller. The information can be displayed on the control unit display and if necessary "disposed of" in a SCADA system via a serial interface. (see Figure 1).

2. Main menu



The main menu can be accessed from the monitor, life and measurement transducer displays from the setup screen by pressing the <Menu> button.

2.1 Monitor



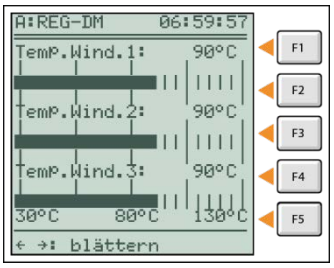
The basic monitor display shows either the oil temperature or winding temperature in decimal form and a bar graph. In addition, the viewer is still informed about the current cooling stage. The winding temperature displayed is the maximum value of the three calculated winding temperatures.

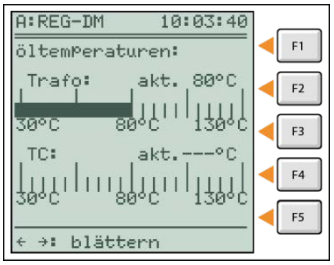
The oil temperature is displayed whenever the oil temperature is selected as the basis for regulating the temperature or the fan and oil pump control. The winding temperature is displayed if either the "Smart Fan Control" (SFC) or the winding temperature is selected as the basis for the temperature control.

Transformers can be equipped according to type of construction with multiple fan groups. Since the fans are considered similar to your cooling performance here, a greater cooling capacity is achieved by the simultaneous operation of multiple fans Cooling stage 3 is then when three fan groups are working simultaneously, cooling stage 1 is when one group of fans is working.

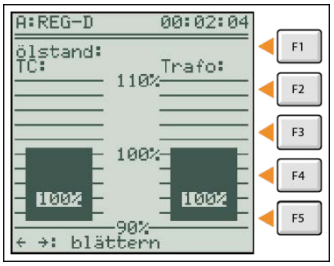
The control of the fans can be done either manually or automatically. For manual control, the REG-DM must be set to HAND. The cooling stages can then be progressively activated or deactivated using the orange up arrow and down arrow buttons. When the REG-DM is in AUTO mode, the fan is controlled automatically.

With the "→" key the next monitor screen can be accessed. Here, depending on the selected control base, either the oil temperature of the transformer and the tap changer or the hot-spot temperature of all three windings is displayed.

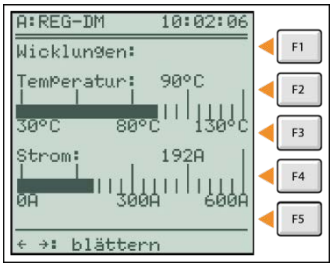




With the "→“ key the next monitor screen can be accessed, on which the fill levels of the transformer tanks and the TC (⇒ Tap Changer ⇒ step switch) are displayed.



With the "→" key the next monitor screen can be accessed, on which the winding temperature and the currently flowing current are displayed.



2.1.1 Oil level (TC/Trafo)

The oil level in the transformer and the tap changer can only be displayed when the controller is supplied with the corresponding sensor data from the transformer and the tap changer. In the simplest case, the level is supplied to the controller via an analogue signal, and the necessary scaling can be carried out from the menu. A water level monitoring can also be displayed in the graph via a digital signal. If the limits are exceeded, the bar flashes. A black non-flashing column therefore acts as a "level is correct" signal.

2.1.2 Oil temperatures (TC/Trafo)

The oil temperatures can be displayed either as bars or alphanumerically. Using the setup, the maximum temperature for the transformer and tap changer can be specified. If the temperature is required in the tap changer vessel, it must be supplied as a mA value analogue input to the controller.

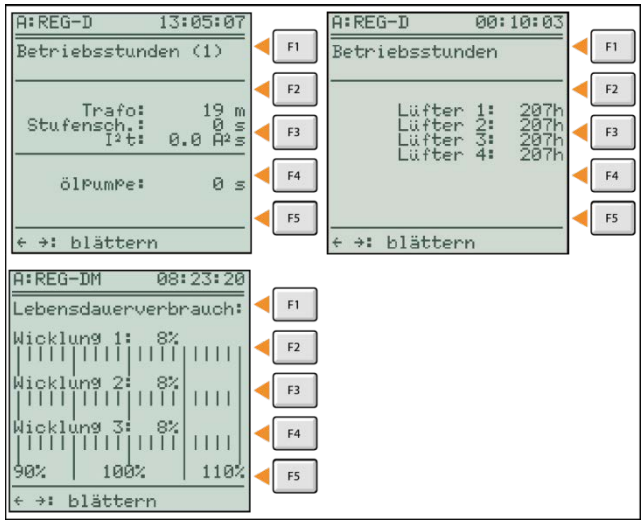
2.1.3 Winding currents and winding temperature

The "windings" display mode gives information about the current current flow through the windings, and the hot-spot temperature value calculated from the current and the oil temperature. The values displayed are the largest current and the highest winding temperature.

2.2 Service life

The "SERVICE LIFE" menu, in which all the lives (transformer, fan, pump) are combined, can be accessed from the "MONITOR" main menu when <F2> is pressed in the "SERVICE LIFE" submenu.

From the current menu, you can reach the MONITOR main menu by pressing <ESC>. The number of <ESC> key presses depends on which menu level you are at.



2.2.1 Operating hours -1

In "Operating hours -1" display mode, the accumulated operating hours of the transformer (transformer under power), the tap changer and the oil pump are displayed. Different operating hours for transformer and tap-changers are the rule, because in the case of the tap changer, only the time is measured when the motor drive is in operation. The "operating lamps-time" is used as an indicator of the tap changer operating hours. This means that the life counter is only active for the tap changer when a digital input is configured as "operating light" (07: Operating light).

If, despite the configured input, no operating lamp is connected, the counter value does not change. If no digital input is configured, the program uses the operating lamps maximum time configured in the controller SETUP 5 (Functions..., F1).

In this case, whenever the controller issues a setting command, the tap changer life counter is incremented by the preset time.

The operating hours of the transformer are recorded as standard if a voltage is set on the secondary page with the "transformer in operation" information.

This approach can, depending on the location of the voltage converter, lead to erroneous results (see Figure 7).

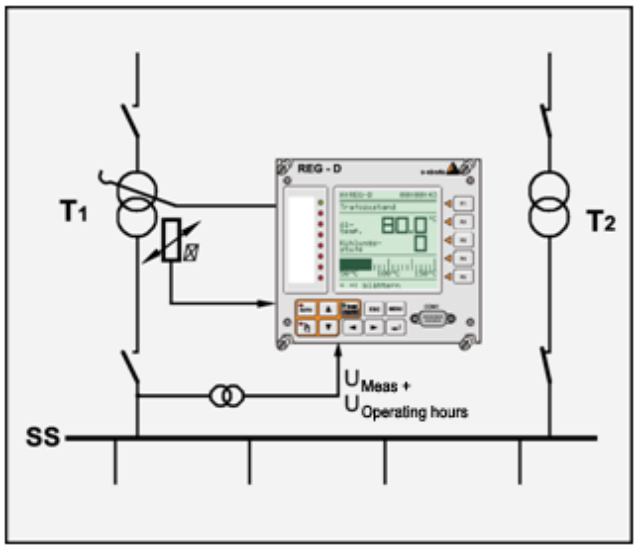


Figure 7

In any case, the correct results however provide the measurement of the primary voltage of the transformer. With the firmware feature "three winding", an additional second voltage channel can be activated, which measures the primary voltage. The second input voltage is then always present and in principle available for this task when the controller is equipped with the "M3" or "M9" hardware feature. In all other cases, the regulator – if measurement of the primary voltage is required – must be sent for conversion.

If the "three-winding" software feature is enabled (only possible in combination with the M3 or M9 hardware feature), the operating hours count is derived from the primary voltage.

Is the "three winding" feature is not activated, the operating hours count is derived from the secondary voltage of the transformer from which - for the cause mentioned above - depending on the location of the voltage transformer, can lead to incorrect results.

Figure 7 shows as illustration of an application in which the two transformers are fed from a busbar.

If the voltage transformer is mounted close to the bus bar, the controller will then also measure a voltage when the secondary of transformer T_1 is switched off because the bus - and thus the voltage transformer - is supplied through the second active transformer T_2.

Although in Figure 8, the secondary control voltage is recorded, the voltage for the operating hours counter is tapped from the primary-side of the voltage converter. This version does provide a correct recording of the operating hours.

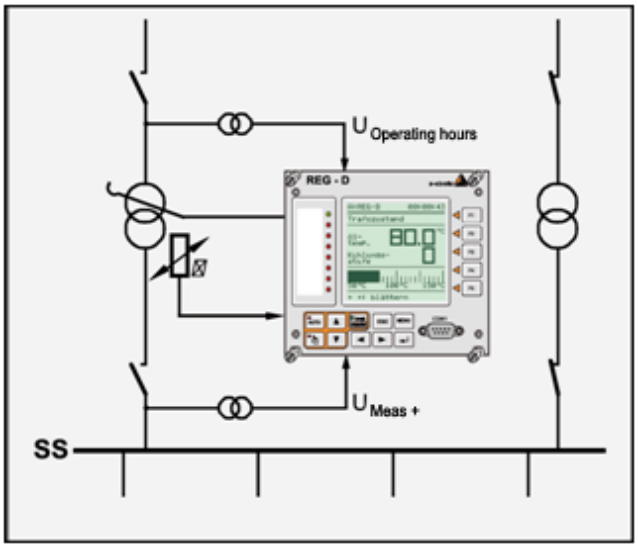


Figure 8

With the value I^2t a measurement is provided for estimating the contact erosion in the tap changer. Two parameters are needed to determine this measurement. One is the arc current and the other the time "t" during which the arc exists. The current "I" is used as the current which flows at the time of switching, while the time "t" can be switch-specific. It should be noted that the switching time is very difficult to determine accurately and, on the other hand, is also not constant over the life of the switch. However, the accumulation of I^2t values provides a way to capture the condition of the tap changer. If the time "t" is set to 1, the value of the product I^2t corresponds to I^2.

Is the oil pump is controlled by the controller, the operating time of the pump is totalled and displayed in the menu.

2.2.2 Operating hours -2

Under the heading “Operating hours -2” the operating times of the fan and the oil pump are listed.

The control of the fan uses an algorithm that ensures that each time the fan is switched on, its total operating time is the smallest.

This ensures that all the fans are approximately evenly loaded.

Via the menu the system can also be set up so that a specific output is associated with a certain cooling group. The oil pump is, however, always associated with a fixed output relay.

2.2.3 Lifetime consumption

The "Lifetime consumption" information is derived from the equations specified in CEI/IEC 354/ VDE 0536.

The lifetime consumption should not be confused with the operating hours described earlier. The "Operating hour" register only counts the time where the transformer is under voltage, while the thermal ageing is taken into account in the lifetime consumption.

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

$$Lifetime = e^{(\alpha+\beta)/T}$$

α and β : Constants, which are determined by tests on the isolation

T : thermodynamic temperature in K

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

$$Lifetime = e^{-P\Theta}$$

P : Constant

Θ : Temperature in °C

According to scientific publications the lifetime consumption in transformers in the range of 80 to 140 °C doubles when the temperature increases to about 6 K.

The relative service life consumption at a temperature Θ_h, relative to the normal service life consumption at a temperature Θ_{hN}, can be determined from another further equation.

$$V = \frac{Lifetime\ consumption\ at\ \Theta_h}{Lifetime\ consumption\ at\ \Theta_{hN}} \qquad (1)$$

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

The value Θ_{hN} for a transformer is specified according to CEI/IEC 354 / VDE 0532 Part 1/11.71 as 98 °C. This temperature corresponds to the operation of a transformer at rated load at 20 °C coolant temperature, when the hot-spot temperature is 78 K, i.e. 13 K above the average over temperature of 65 K. These temperature conditions correspond to the normal aging of the insulation.

From equation (1) with Θ_{hN} = 98 °C the following equation can be derived in decadic logarithms.

$$V = relative\ Lifetime\ consumption = 10^{(\Theta_h - 98)/19{,}93} \quad (2)$$

This relationship is shown in the following table:

Θ_h in °C	Relative service life consumption V
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 x 2) + (14 x 0.25) = 23.5 hours

Service live consumption during 24 hour operation.

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

If the load and ambient temperature are constant, the relative service life consumption is calculated using the equation V x t. where "t" is the time under load and V is the relative service life consumption from equation (1).

In the general - the operating conditions are not constant - the service life consumption of the transformer is calculated using the following equation:

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

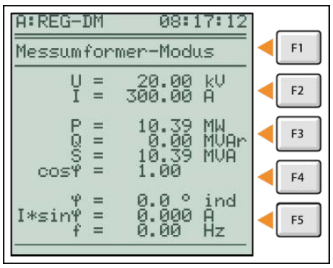
n : Number of a time interval

N : Total number of the same time intervals

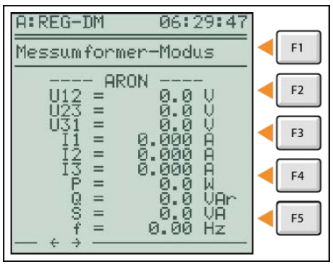
2.3 Transmitter mode

In the basic monitor display first press <Menu>, and then the <F3> Key to enter transmitter mode.

Here the current voltage, current, power and power factor are displayed.



If your REG-DM has the M2 feature, in the menu the display of the voltage, current and power measured in the Aron switch is available.



2.4 SETUP

From the basic monitor display you can enter the Setup by pressing the <Menu> key twice.

2.4.1 SETUP 1

With the <F2...F4> keys the individual submenus can be selected.

2.4.1.1 Trafo Parameter

..... multiple sets

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.

- From the parameter set, the next cooling stages can be selected with the <F1> key.

Rated current

The rated current of the winding may differ depending on type of cooling. Please note that the rated current primary value is also used for measuring the primary current.

The rated current appearing in this menu must not be confused with the rated value of the current that is used for measuring tasks in the controller (SETUP 5, F2 ff).

The rated current is configured as 1A or 5A there. The nominal value of the current in relation to the transformer monitoring is the current that can be "expected" in the transformer with a certain cooling.

The display of the current can be adjusted in the range of 0...3000 A.

- To enter the respective nominal current, first press the <F2> key.
- For entry, please use the <F1...F5> function keys.
- The entry must be ended with <Enter>.

Thermal time constant of the winding

The thermal time constant is a transformer-specific parameter and can be taken as a rule from the transformer data sheet.

Range of values: 0..50000 s

Contact with the manufacturer may be required.

The time constant of the winding is the time that elapses multiplied by five until the hot spot has reached the stationary final value.

Example:

With a time constant of 3000 seconds, it is assumed that after 5 x 3000 s = 15,000 s, so after about 4 hours, the stationary final value of the hot-spot temperature will have been reached.

The number of submenus is determined in accordance with the predetermined cooling stages. "Cooling stage 0" indicates no cooling, "Cooling stage 0 (oil pump)" appears only when one of the two types of cooling ON/OF or ON/OD is configured. In the "Cooling stage 1,2,..." menus the transformer parameters for the respective cooling stage (fan group) are entered.

Hot-Spot Temperature Increase Hg_r

The hot-spot temperature increase (Hot-Spot Temp. Inc.) is a transformer-specific parameter and can be taken as a rule from the transformer data sheet.

Contact with the manufacturer may be required.

If no manufacturer data is available for "Hg_r", it is recommended to use the values specified in the standard.

The standard specifies that different values for the hot-spot temperature rise "Hg_r" should be used for medium and large power transformers according to the type of cooling.

Type of cooling	ON...	OF...	OD...
Hg_r	26 K	22 K	29 K

For distribution transformers with ONAN cooling, a value of 23 K is proposed.

Winding exponent y

The winding exponent "y" is a transformer-specific parameter and can be taken as a rule from the transformer data sheet.

Contact with the manufacturer may be required.

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

The standard specifies that different values for the winding exponent "y" should be used for medium and large power transformers according to the type of cooling.

Type of cooling	ON...	OF...	OD...
Y	1.6	1.6	2.0

For distribution transformers with ONAN cooling, an exponent value of 1.6 is proposed.

2.4.1.2 Basis of the control

For the connection of the individual fans, different reference temperatures can be chosen. Because there is a formulaic relationship between the oil and the winding temperature, in principle, both temperatures can be used as the base temperatures.

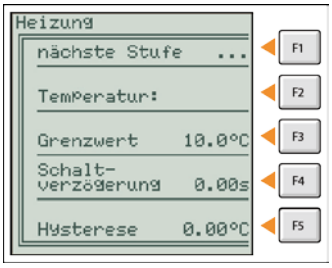
To enable allow the user to maintain their operational philosophy, the rule base can be selected.

- The base can be chosen using <F3> in <SETUP 1 Control>.

The following can be chosen:

- Oil (the oil temperature determines the limits)
- Winding (the winding temperature determines the limits)
- SmrtCtrl (Smart Fan Control): In this mode, the expected winding temperature is calculated and used to control the cooling.

2.4.1.3 Temperature limits



..... multiple sets

Individual limit values can be configured for each cooling stage, for 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 3").

When the temperature exceeds the specified limit, the appropriate cooling stage is activated.

- The limit can be set in the range from -30 °C to 200 °C using the <F1...F5> function keys.
- The chosen limit must be confirmed with <Enter>.
- From the parameter set, the next cooling stages can be selected with the <F1> key.

Switching delay

To force a "calm" running profile for the respective fan, the temperature must exceed the limit for a configurable time before the fan is switched on.

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

The sensitivity of the fan control can be adjusted using the switching delay. In this way, transient temperature increases which may occur due to interference on the transmission can be suppressed.

Hysteresis

If the temperature varies around the set limit value, without specifying the hysteresis it would be impossible to prevent the fan being repeatedly switched on and off.

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

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

2.4.2 SETUP 2

SETUP 2 is accessed by pressing the "→" arrow or the <F1> key in SETUP 1.

2.4.2.1 Type of cooling

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 one oil pump is available:
- ON/OD: stands for switching between ON and OD cooling. In this case, one device for the directional guidance of the oil stream is available.

When the cooling modes ON/OF and ON/OD are activated in the "transformer parameters" and "temperature limits" menus, one additional parameter page for the oil pump is available.

2.4.2.2 Fan assignment

To enable the user to choose to assign a specific fan to a cooling stage or to leave it to the system to decide which fan to activate for a cooling stage, the Transformer Monitoring Module offers the choice between:

- fixed

and

- cyclic

If the parameter "fixed" is chosen for the assignment of a fan to a specific cooling stage, for that cooling stage 1 fan 1 will always be switched. Over a long operating time this setting,

however, leads to the operating time and the wear of fan 1 being very large and that of the higher cooling stages being very small.

However, if "cyclic" is chosen for the fan assignment, the controller decides on the basis of the total operating time of each cooling stage which fan is switched. Over the service life, this algorithm achieves an approximately equal duty time for all fans.

2.4.2.3 Number of fans

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

There are in total 6 fan cooling groups available, which are identified in the menu by the numbers 1: to 6:.

2.4.2.4 Current measurement

The hot spot of the transformer is influenced by various transformer parameters (Hgr, y, time constant) and by both the measured quantities oil temperature and current through the winding. For different applications, different sources for current measurement are available. The necessary settings can be made in the "Current Measurement" setup.

Transducer connection

In the "Transducer connection" submenu the current to be used for the hot-spot temperature calculation can be selected. The effect of this parameter depends on the "three-winding" and "M2" features. For this, please refer to the note below.

Conversion of the transformer

In order to record the primary current in the secondary current measurement, the current measured can be converted to the primary side using the power transformer conversion ratio. This setting is only required for secondary current measurement.

Tap changer switching time

The value I^2t is used for the qualitative recording of the contact load in the tap changer. The current for the determination of I^2t is taken from the continuous measurement of the current, while the switching time "t" can be regarded as a tap changer specific value.

Although no specific information is available for the tap changer, sufficiently good results are achieved with a switching time in the range of 0.02 to 0.06 s.

- So press the <F5> key to enter the assumed switching time of the tap changer.
- This entry must also be ended with <Enter>.

Influence of the "three-winding" and "M2" features as well as the "Transducer connection" parameter on the current consumption

Measurement of the winding current:

- Without M2 and no three-winding:
  - Prim.: calculated primary value
  - Sec.: Secondary value (value measured at Transducer 1)
- With M2 and no three-winding:
  - Prim.: 3-phase with conversion to Prim.
  - Sec.: 3-phase without conversion to Prim.
- Without M2 and with three-winding:
  - Prim.: Primary value (value measured at Transducer 2)
  - Sec.: Secondary value (value measured at Transducer 1)
- With M2 and with three-winding:
  - Prim.: 3-phase with conversion to Prim.
  - Sec.: 3-phase without conversion to Prim.

If the calculated or measured primary values are used for the current, the primary values must also be used for the settings in the monitor!

Calculation of the I^2t value:

- Without M2 and no three-winding:
  - Prim.: calculated primary value
  - Sec.: calculated primary value
- With M2 and no three-winding:
  - Prim.: max. value without conversion
  - Sec.: max. value without conversion
- Without M2 and with three-winding:
  - Prim.: Primary value directly at Transducer 2
  - Sec.: Primary value directly at Transducer 2
- With M2 and with three-winding:
  - Prim.: Max. value without conversion
  - Sec.: Max. value with conversion

The calculated primary value is determined from the measured secondary current and the conversion ratio of the transformer.

"Prim." and "Sec." refer to the setting of the "Transducer connection" parameter.

2.4.3 SETUP 3

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

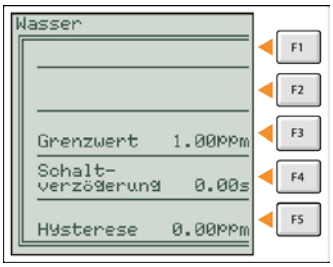
For monitoring the water and gas content, as well as for the oil level and oil temperature (transformer, TC) SETUP 3 "alarm" is available.

With <F2...F5> other submenus can be accessed in which limits, switching delays and hysteresis can be selected.

Since the logic of each submenu is similar, the comments on the individual screens are kept concise. Note, however, that the hardware requirements must be met so that the measured variables, which are usually supplied via external transducers, can be received as mA signals by the controller.

The total number of six analogue channels can be expanded using analogue interface cards (ANA-D) at any time (see the section "Increasing the system hardware resources").

2.4.3.1 Water content



Limit

Defines the switch-on point for the alarm signal.

Setting range: 0...10000 ppm

Switching delay

Defines the switch-on delay for the alarm signal.

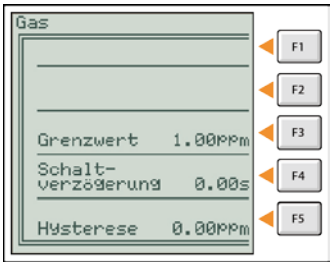
Setting range: 0...900 s

Hysteresis:

Defines the hysteresis for the switching point.

Setting range: 1...100 ppm

2.4.3.2 Gas content



Limit

Defines the switch-on point for the alarm signal.

Setting range: 0...10000 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...100 ppm

2.4.3.3 Oil temperature (TC)

Maximum

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.

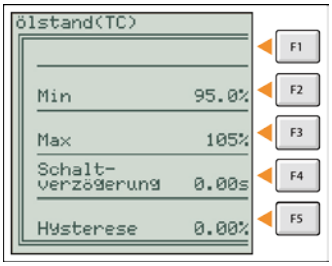
Setting range: 0...900 s

Hysteresis

Defines the hysteresis for the switching point.

Setting range: 1...30 K

2.4.3.4 Oil level (TC)



Minimum

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

Setting range: 0 … 150 %

Maximum

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.

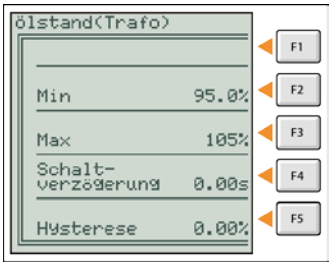
Setting range: 0...900 s

2.4.4 SETUP 4

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

In SETUP 4 the limits for the oil level (transformer), oil temperature and the winding temperature can be entered.

2.4.4.1 Oil level (Trafo)



Minimum

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

Setting range: 0 … 150 %

Maximum

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.

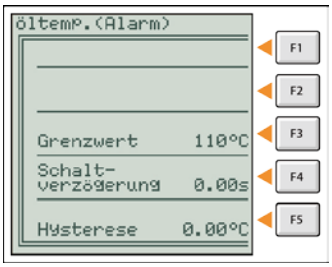
Setting range: 0...900 s

Hysteresis

Defines the hysteresis for both switching points.

Setting range: 1 … 30 %

2.4.4.2 Oil temperature (Alarm)



Limit

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.

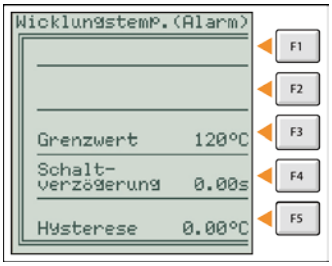
Setting range: 0...900 s

Hysteresis:

Defines the hysteresis for the switching point.

Setting range: 1...30 K

2.4.4.3 Winding temperature (Alarm)



Limit

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

2.4.4.4 Winding temperature (Trigger)

Limit

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

2.4.5 SETUP 5

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

2.4.5.1 Analogue inputs and outputs

The physical parameters for the temperature (transformer, tap changer) or level (transformer, tap changer), water content, gas in oil, etc. can be supplied to the REG-DM using mA signals.

Each REG-DM can be equipped with up to three analogue modules, each of which provides either two analogue inputs or two analogue outputs.

The position of the module is arbitrary. The controller automatically detects the type of assembly in each slot and adaptively activates the relevant menus.

Input and output functions

The assignment of a specific input or output to a particular measurement is realized with the help of input and output functions.

The following input functions can be chosen:

Input function	Description
OFF	switched off, no function
PROG	programmable, analogue input is evaluated by the H program
iT_Oil	Oil temperature (Trafo) when only one oil temperature is used
iT_Oil1	Oil temperature winding 1
iT_Oil2	Oil temperature winding 2
iT_Oil3	Oil temperature winding 3
iT_OilTC	Oil temperature (tap changer)
iOillevTC	Oil level (tap changer)
iOillevTr.	Oil level (Trafo)
iWasser	Water in oil
iGas	Gas in oil

The following output functions are available:

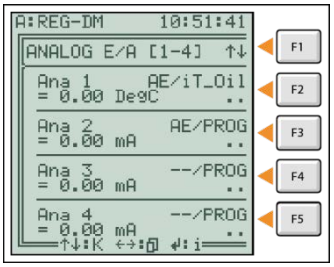
Output function	Description
OFF	switched off, no function
PROG	programmable, analogue output is evaluated by the H program
oZero	Output 0 mA
o+FullRng	Output of the positive max. value
o-FullRng	Output of the negative max. value
oU	active measurement voltage
oP	Active power
oQ	Reactive power
oS	Apparent power
oU1	Measurement voltage at Transducer 1
oU2	Measurement voltage at Transducer 2
oI1	Current 1
oI2	Current 2
oI3	Current 3
oPHIDEG	Phase angle
oCOSPHI	cos (phi)
oFREQ	Frequency
oOilTemp	Oil temperature
oWindTemp	Hot-spot temperature of the winding
oT_Wind1	Hot-spot temperature winding 1
oT_Wind2	Hot-spot temperature winding 2
oT_Wind3	Hot-spot temperature winding 3

The input function PROG is always selected if a measurement value not provided for is used.

In principle, any arbitrary measurement value that can be represented as a mA value can be supplied to the controller, processed and displayed.

If necessary, limits can of course be derived from such "non-standard-inputs" and output by relay. To do this, please contact the head office.

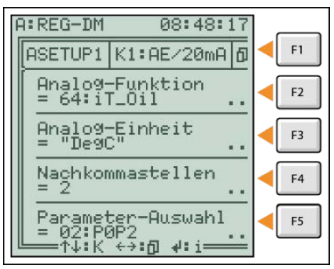
Configuring the analogue channels



- By pressing the <F2...F5> keys the channel to be configured can be selected.
- Using the "→" key the display of the analogue value can be switched. The display of either the normalized values (relative to the nominal value of the channel), the scaled values (with the parameterized scale and the unit) or the real mA value can be chosen.

The following figures show the configuration of Channel 1. For the acquisition of the oil temperature 0... 100 °C, 4.. 20 mA is configured.

- Channel 1 is selected with the <F2> key.



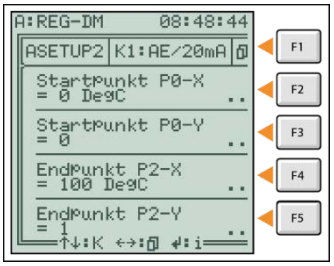
- The function of the analogue channel is selected with the <F2> key.
- A list of all available functions appears:
- The required function can be selected with the <F1, F2> and <F4, F5> keys.
- The input must be ended by pressing the <F3> key.
- The units of the scaled signals can be set with the <F3> key.
- The number of decimal places can be set with the <F4> key.
  The preceding settings affect only the representation of the values in the analogue main menu and not on the processing or display in the monitor.

The type of curve to be used for scaling the mA signal can be set with the <F5> key.

The following options can be chosen:

All:	all parameters are available
Fac+Off:	Scaling using factor and offset
P0P2:	linear scaling
P0P1P2:	Scaling with a breakpoint

For our example we use the "iT_oil" input function. The unit °C and two decimal places are selected automatically. For the scaling we use a linear characteristic curve.



The ASETUP 2 menu is accessed with the <F1> key.
The actual scaling is made here.

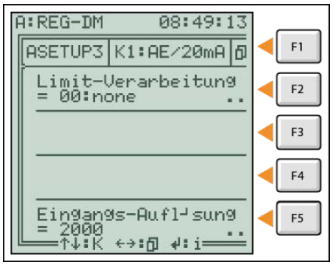
The start point for the measurement value is set with the <F2> key. In our case 0 °C (input without units).

The start point for the mA value is set with the <F3> key. The input is made in standardised form, i.e. derived from the nominal value of the module. In our case 0.2
(4 mA / 20 mA = 0.2).

The start point for the measurement value is set with the <F4> key. In our case 100 °C (input without units).

The end point for the mA value is set with the <F5> key. The input is made in standardised form, i.e. derived from the nominal value of the module. In our case 1
(20 mA / 20 mA = 1).

The nominal value of the module appears at the top centre of the display, next to the channel number. If you use the non-linear characteristic curve, there are two additional bases.



The ASETUP 3 menu is accessed with the <F1> key.

The limit for the analogue channel can be set with the <F2> key.

The following options can be chosen:

none:	no limit
High:	Limit on exceeding the specified maximum values
Low:	Limit on going below the specified minimum values
High+Low:	Upper and lower limit

For example, if "none" is selected, the characteristic curve is extended beyond the bases. In our case this means that a current value of less than 4 mA results in an oil temperature of less than 0 °C. If the bottom limit is triggered, a current value of less than 4 mA results in an oil temperature of 0 °C.

The triggering of an analogue input can be set with the <F5> key.

2.4.5.2 Digital inputs and outputs

The REG-DM can accommodate various control signal as a digital signal and output its control signals via relay outputs.

Digital input and output functions

The following input functions are available:

Input function	Description
0: AUS	OFF
1: PROG	Input is used by the H program
2: Auto	Auto
3: Hand	Manual
4: HandAuto	Manual, Auto, pulse controlled
5: BuchAlm	Buchholz alarm
6: BuchTrip	Buchholz trigger
7: BuchTC	Tap changer Buchholz alarm
8: Laufl.	Operating lamp signal

The "Buchholz Alarm" and "Buchholz Trigger" signals must be supplied to the controller by a separate Buchholz relay and can then be “passed” to a supervisory control system via a corresponding control coupling.

The following output functions are available:

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

Output function	Description
0: AUS	no function
1: PROG	Output is used by the H program
2: EIN	ON
3: Heizung	Heating on
4: Ölpumpe	Oil pump on
5: Kuehler 1	Fan group 1 on
6: Kuehler 2	Fan group 2 on
7: Kuehler 3	Fan group 3 on
8: Kuehler 4	Fan group 4 on
9: Kuehler 5	Fan group 5 on
10: Kuehler 6	Fan group 6 on
11: ÖlAlarm	Oil temperature alarm
12: WndAlarm	Winding temperature alarm
13: WndAusl	Winding temperature trigger
14: T_ÖITC	TC oil temperature alarm
15: Wasser	Water limit exceeded
16: Gas	Gas limit exceeded
17: ÖlstTC+	TC high oil level
18: ÖlstTC-	TC low oil level
19: ÖlstTr+	Trafo high oil level
20: ÖlstTr-	Trafo low oil level
21: Buchalm	Buchholz alarm
22: BuchTrip	Buchholz trigger
23: BuchTC	Tap changer Buchholz alarm
24: ELAN-L	Communication to ELAN-L
25: ELAN-R	Communication to ELAN-R
26: ELAN-Err	ELAN error
27: AUTO	Automatic operation
28: Laufl.	Operating lamp signal

The assignment of a specific control function (e.g. "Oil pump" or "Fan group") to a specific relay output must be done in the controller menu.

To illustrate the procedure, the configuration at this point will be described as an example.

Configuring the digital inputs and outputs

On the right of the screen the current function assignments are displayed.

- Using the <F2...F4> keys the appropriate input can be selected.
- With the <F1> key the next four inputs can be scrolled.
  After selecting one of the inputs the list of available input functions is displayed.
- The required function can be selected with the <F1, F2> and <F4, F5> keys.
- The selection must be confirmed with the <F3> key.

The same procedure applies for the relay and LED functions.

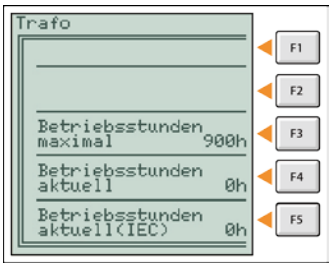
2.4.6 SETUP 6

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

The "Service life" submenu in the main menu is used to enter the maximum service life of the currently elapsed operating hours of the various equipment. This is always required when the monitoring system is installed in an existing in-service transformer.

But also when individual equipments are replaced, the "Service life" parameter can be set as required via this menu.

2.4.6.1 Transformer service life



Maximum operating hours

With <F3> , the expected maximum service life (see the manufacturer's instructions) can be entered.

Setting range: 0...999999 hrs

Current operating hours

Here the current operating hours (see the section "Operating hours -1") of the transformer can be adjusted. This setting is always important when the system is not installed at the same time as the transformer. In conjunction with revisions, adjustments may also be needed.

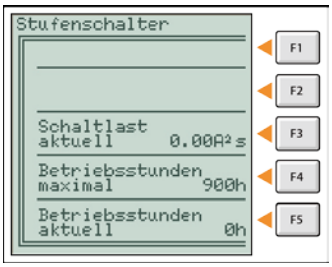
Setting range: 0...999999 hrs

Current operating hours (IEC)

Adjustment of the operating hours in accordance with the IEC is possible here.

Setting range: 0...999999 hrs

2.4.6.2 Tap changer service life



Switching load

The current switching load of the tap changer can be adjusted here.

Setting range: 0...3000 A^2s

Maximum operating hours

With <F4> , the expected maximum service life (see the manufacturer's instructions) can be entered.

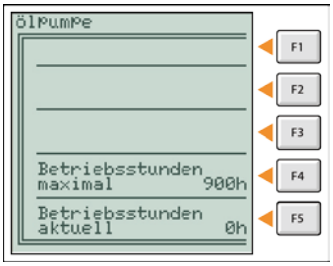
Setting range: 0...999999 hrs

Current operating hours

The "Current operating hours" parameter is always important when the system is not installed at the same time as the tap changer. In conjunction with revisions, adjustments of both parameters may also be needed.

Setting range: 0...999999 hrs

2.4.6.3 Oil pump



Maximum operating hours

With <F4> , the expected maximum service life of the oil pump (see the manufacturer's instructions) can be entered.

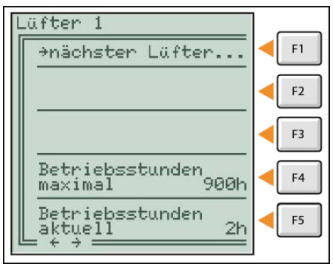
Setting range: 0...999999 hrs

Current operating hours

The "Elapsed operating hours" parameter is always important when the system is not installed at the same time as the transformer and thus the oil pump. In conjunction with revisions, adjustments of both parameters may also be needed.

Setting range: 0...999999 hrs

2.4.6.4 Fan



... multiple pages

According to the number of fans used, multiple pages are used.

Maximum operating hours

The "Elapsed operating hours" parameter is always important when the system is not installed at the same time as the transformer and thus the fan groups. In conjunction with revisions, adjustments of both parameters may also be needed.

Setting range: 0...999999 hrs

Current operating hours

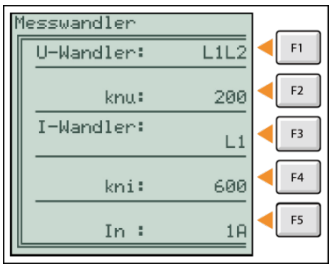
With <F5> the current age of the fan can be entered.

Setting range: 0...999999 hrs

2.4.7 SETUP 7

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

2.4.7.1 Transducer installation



The transducer data can be entered here. If the "Three-windings" feature is active, two KNU and KNI are available.

CAUTION	**Please note that when changing the nominal transducer current a jumper inside the REG-DM must also be moved.** Please follow the instructions in the REG-D manual or contact the head office.

2.4.7.2 RS232

In this menu, the settings for the two RS 232 interfaces of the REG-DM can be made.

Note!

For the transfer from H programs a baud rate of 9600 baud has proven to be optimal.

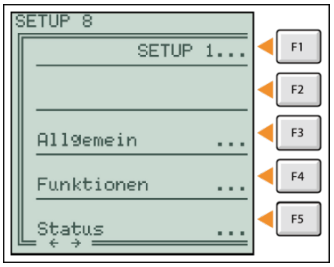
2.4.7.3 ELAN

The settings for the communication between the REG-SYS devices via ELAN can be set here.

If this concerns a connection with multiple devices, please make sure that on the same bus exactly two devices are terminated.

2.4.8 SETUP 8

SETUP 8 is accessed by pressing the "→" arrow or the <F1> key in SETUP 7.



2.4.8.1 General

In the "General 1" menu the identifier of the controller, the device name, date and time, and the contrast of the LCD can be set.

The identifier is the identification of the controller and consists of a letter and a number, if necessary. If multiple controllers are connected to the ELAN, they must have unique identifiers to enable fault-free operation. The device name is just a text string and anything can be entered.

In the "General 2" menu the password can be set and changed to restrict access to the REG-DM.

2.4.8.2 Functions

The language, screen saver (activation after 60 min) and the behaviour after a power supply interruption can be set here.

If the parameter "Manual after Reset" is set to "Yes", the controller will be in manual mode after a reset (sysreset or power supply interruption).

If the parameter is set to "No", the controller will be in the same mode as it was before.

2.4.8.3 Status

Information about the firmware version of the REG-DM, the size of the RAM and the condition of the battery can be read out here.

3. Retrofitting of analogue inputs and outputs

For the procedure for retrofitting analogue inputs and outputs, please refer to the following instructions.

CAUTION	**The work must be carried out professionally!** The ESD directives nust also be followed here.

Procedure:

- Remove the REG-DM from the chassis or housing.
- Connect the analogue module to the REG-CPU CPU circuit board. Please refer to Figures 10 and 11 for this.
- Replace the REG-DM in the chassis or housing.
- Please verify on the basis of your project documentation, whether the necessary wiring is available in the chassis or its housing.
- If this is not the case, please get in touch with the head office.

Pinout for analogue modules

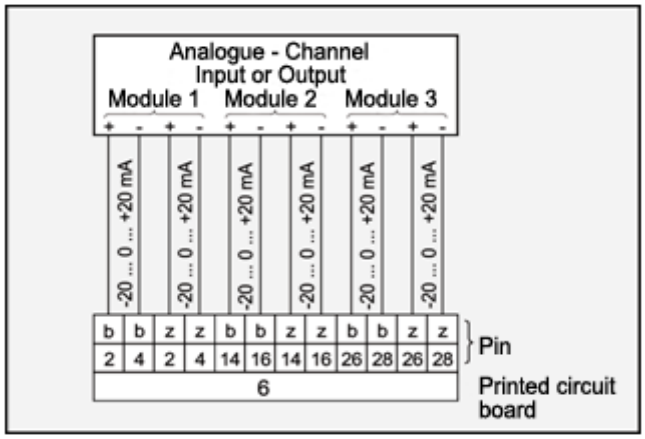


Figure 9

After insertion of the analogue double modules, the modules are automatically detected and processed accordingly. The following channel assignment applies:

- 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
- Module 3.2 - Channel 6

- If needed, load additional H or P programs in the controller (Update32.exe).

Location of the analogue modules

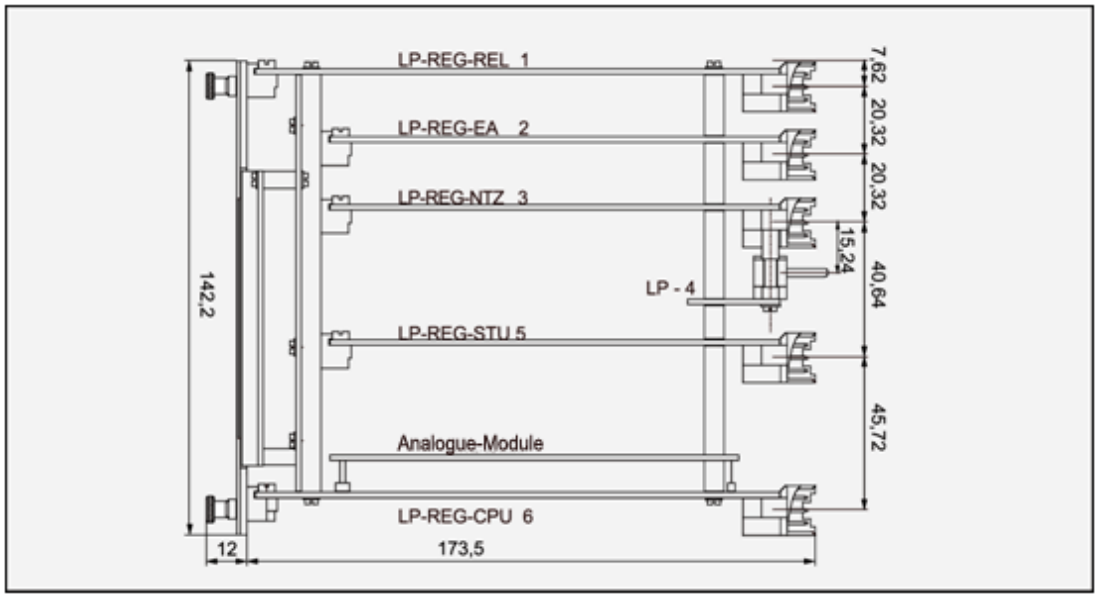


Figure 10

Slot for analogue modules

REG-CPU circuit board

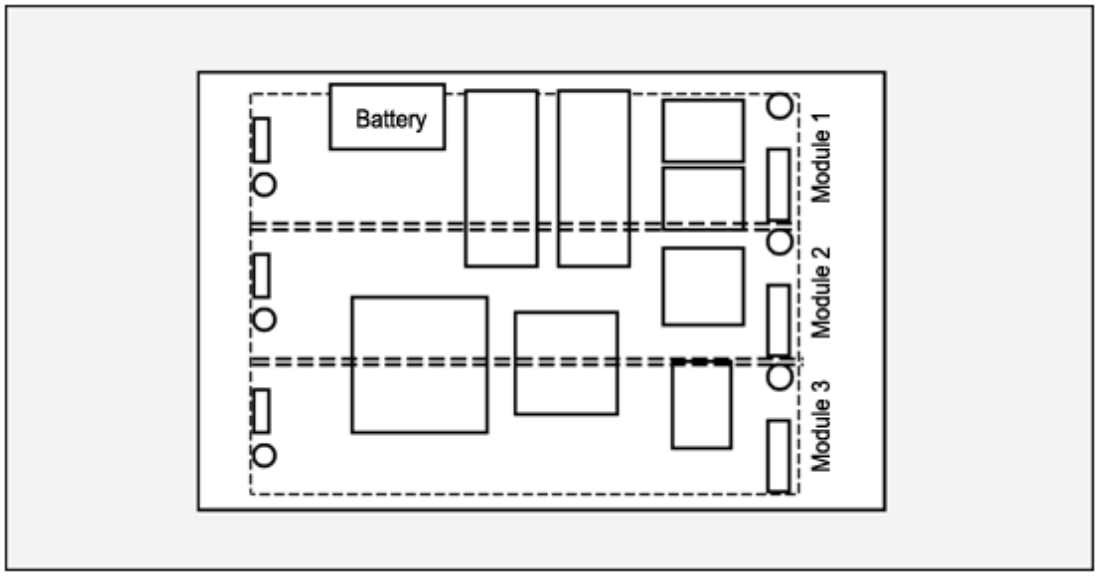


Figure 11

4. Increasing the hardware-based system resources

To increase the number of channels on the controller interface COM 3 (RS485), multiple interface cards can be connected. There are interface cards available for analogue inputs and outputs (ANA-D) as well as digital inputs and outputs (BIN-D).

Additional information channels through BIN-D and D-ANA are usually assigned by background program.

For performance reasons, the total number of interfaces at the COM 3 should not exceed six.

4.1 Additional analogue inputs and outputs

The ANA-D interface card can be supplied with either eight analogue inputs or eight analogue outputs. Mixtures of inputs and outputs on one card are not possible (see Figure 14).

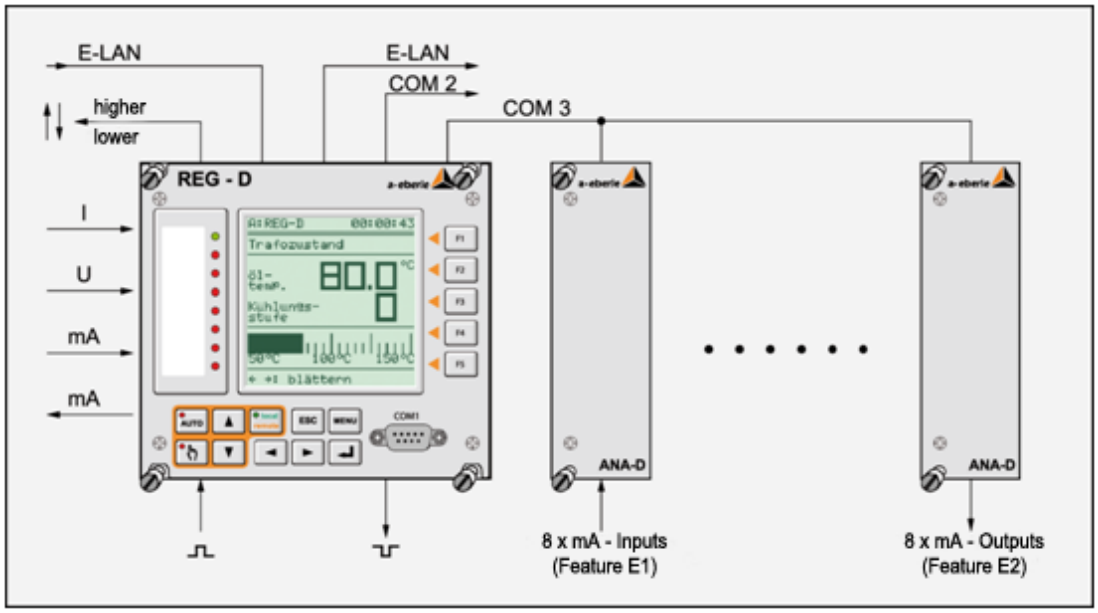


Figure 12

4.2 Additional digital inputs and outputs

The BIB-D interface cards can be supplied with either eight relay outputs or sixteen optically decoupled digital inputs.

Mixtures of inputs and outputs on one card are possible on request.

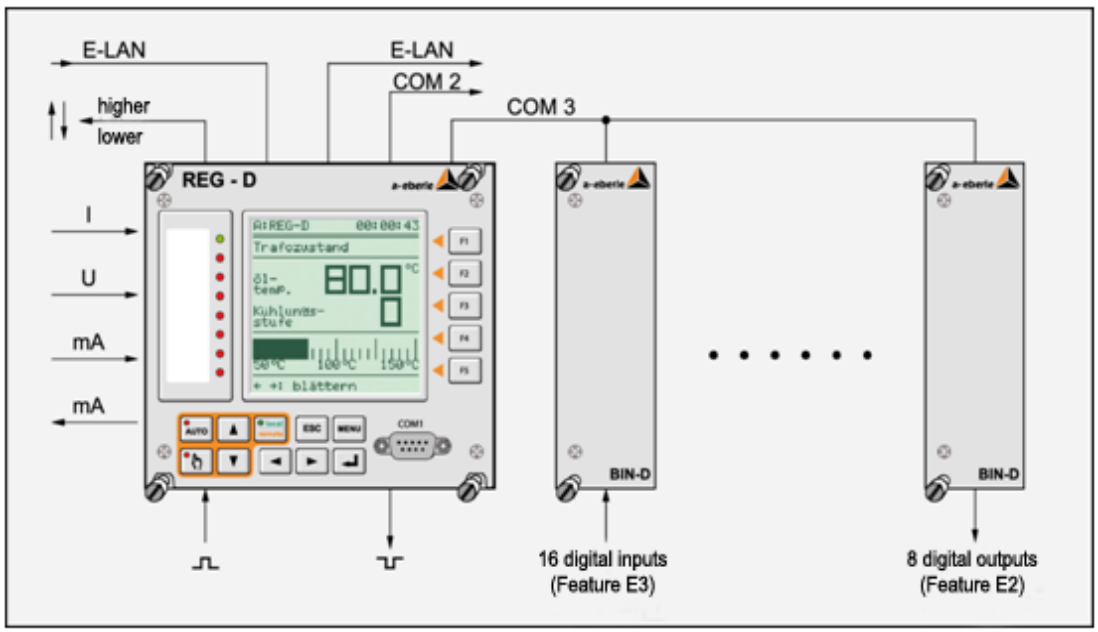


Figure 13

4.3 Combinations of analogue and digital inputs

Interface cards in the ANA-D and BIN-D series can be mixed at the COM 3 as desired.

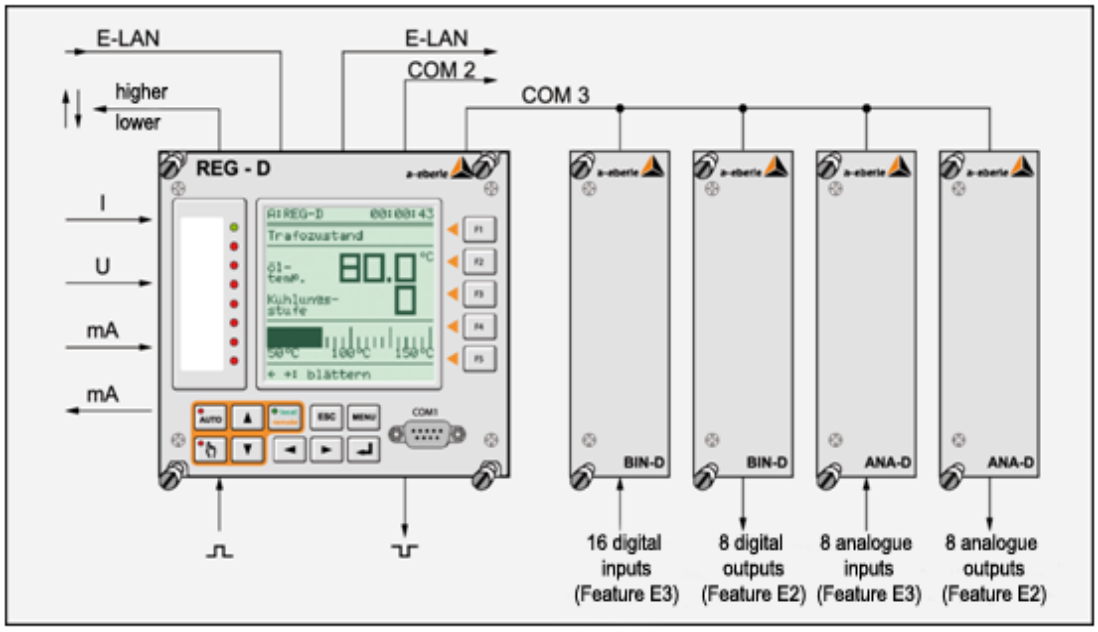


Figure 14

5. Temperature measurement

For the acquisition of oil temperature there are, as already described earlier, two options:

- The temperature signal is supplied by an upstream temperature transmitter as a 4 .. 20mA signal.
- The temperature signal is supplied by a PT-100 sensor in a 3-wire circuit.

For more details about the installation of the transmitter, please refer to the detailed instructions.

5.1 Accuracy considerations

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

The calculation of the hot-spot temperature from the measured oil temperature introduces no additional errors.

The measurement chain:

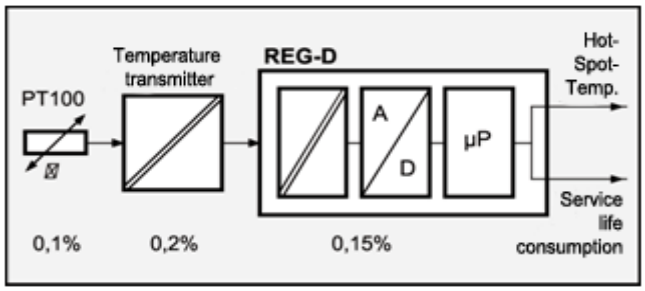


Figure 15

The error determination:

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

the average error is:

$$F_m = \sqrt{0{,}10\ \%^2 + 0{,}20\ \%^2 + 0{,}15\ \%^2}$$

$$F_m = 0{,}26\ \%$$

the maximum error is, however:

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

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

In the case of the inbuilt PT 100 module,

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

Note:

All errors are relative to the full scale measurement value.

6. Guarantee

The REG-DM digital transformer monitoring system is supplied with a warranty for 3 years.

If the controller is retrofitted by an unauthorized agent, this entitlement is void.

If the equipment is returned for conversion to A. Eberle, the entitlement remains in effect.

7. Test Report

A test report for the basic functions of "Record the Hot-Spot Temperature" and "Determination of the Service Life Consumption" can be seen on our home page at www.a-eberle.de.

Notes

A. Eberle GmbH & Co. KG

Frankenstraße 160
D-90461 Nuremberg

Tel.: +49 (0) 911 / 62 81 08-0
Fax: +49-(0)911-62 81 08 96
E-mail: info@a-eberle.de

http://www.a-eberle.de

Software Version:

_____