TD - General Section
Technical Data TD 61

061/03 EN

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1 General

1.1 Validity

This general section applies to the technical data for the following on-load tap-changers (resistance-type fast tap-changer principle), ARS, off-circuit tap-changers, drives and their accessories:

Product	Technical data
VACUTAP® VT®	TD 124
VACUTAP® VV®	TD 203
VACUTAP® VM®	TD 2332907
VACUTAP® VR®	TD 2188029
OILTAP® V	TD 82
OILTAP® MS	TD 60
OILTAP® M	TD 50
OILTAP® RM	TD 130
OILTAP® R	TD 115
OILTAP® G	TD 48
COMTAP® ARS	TD 1889046
DEETAP® DU	TD 266
TAPMOTION® ED	TD 292

Table 1: Overview

The right-hand column contains the document number of the specific technical data for the corresponding product. These documents contain further detailed information about the various product variants and their properties.

The associated assembly instructions, commissioning instructions and/or operating instructions are supplied with the product. These contain descriptions on the safe and proper installation, connection, commissioning and monitoring of the product.

Standards quoted

If standards or guidelines are provided as references without the edition (year of publication) being stated, the version applicable when this document went to print shall apply.

1.2 Subject to change without notice

The information contained in this technical file comprises the technical specifications approved at the time of printing. Significant modifications will be included in a new edition of the technical file.

The document number and version number of this technical file are shown in the footer.

1.3 Mode of operation of on-load tap-changers and off-circuit tap-changers

On-load tap-changers and off-circuit tap-changers are used to set the voltage on transformers. The voltage is set in stages by changing the transmission ratio. To do this, the transformer is fitted with a tapped winding, the taps of which are connected to the on-load tap-changer's tap selector, the ARS or the off-circuit tap-changer.

On-load tap-changers are used for interrupt-free transformer voltage setting under load. Voltage setting with off-circuit tap-changers on the other hand requires the transformer to be fully switched off.

This document refers only to on-load tap-changers following the resistance-type fast tap-changer principle. It mainly looks at issues affecting on-load tap-changers, ARS and off-circuit tap-changers for oil transformers.

1.3.1 On-load tap-changers and off-circuit tap-changers for oil transformers

Most on-load tap-changers and off-circuit tap-changers are designed for countersunk installation in the transformer tank such that the tapped winding take-off leads require little routing to the tap selector or off-circuit tap-changer.

On-load tap-changers are operated by a motor-drive unit. The motor-drive unit is connected mechanically to the on-load tap-changer head via drive shafts and bevel gears. Off-circuit tap-changers can be operated with either a motor-drive unit or manual drive.

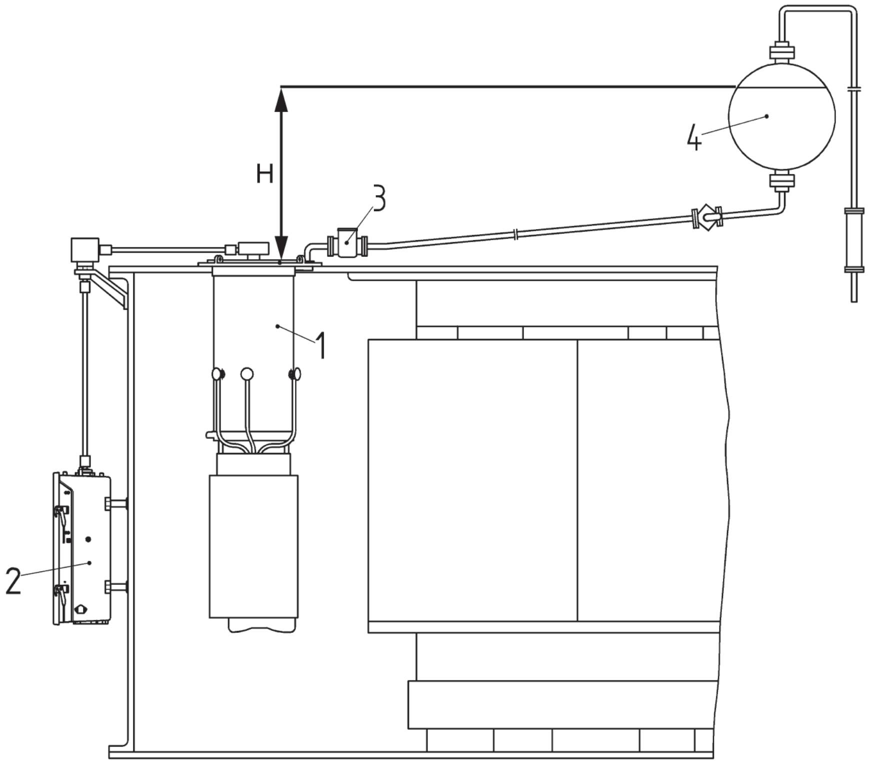


Figure 1: Transformer with on-load tap-changer, schematic presentation

1	On-load tap-changer	3	Protective relay
2	Motor-drive unit	4	Oil conservator for on-load tap-changer oil
H	Height of oil column in oil conservator above the on-load tap-changer head cover		

1.3.2 On-load tap-changers for dry-type transformers

The VACUTAP® VT® on-load tap-changer can be used for interrupt-free voltage setting on dry-type transformers.

The VACUTAP® VT® on-load tap-changer is secured to the active part of the dry-type transformer and has been designed as a single-phase module with direct assignment to one of the transformer legs. A motor-drive unit provides mechanical operation. The single-phase modules can be easily coupled to produce a three-phase system.

1.4 On-load tap-changer function

1.4.1 On-load tap-changer switching concept

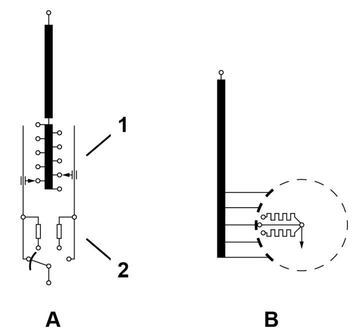


Figure 2: On-load tap-changer switching concept

A	Diverter-switch tap-selector concept	B	Selector switch concept
1	Tap selector		
2	Diverter switch		

1.4.1.1 Diverter-switch tap-selector principle

On-load tap-changers which use this switching principle consists of a diverter switch and tap selector.

The tap selector provides preparatory selection of the desired tap which is then connected to the dead side of the diverter switch. The subsequent diverter switch operation results in this tap then taking on the operating current.

During the tap-change operation, the functions of the diverter switch and tap selector are therefore coordinated.

1.4.1.2 Selector switch concept

On-load tap-changers using the selector switch concept combine the properties of a diverter switch and tap selector. The switch from one tap to the next is undertaken in just one step.

Difference between standard selector switches and those with vacuum technology:

In standard selector switches, the contacts through which the choice of desired tap is made also undertake the diverter switch operation.

In selector switches with vacuum switching technology, the diverter switch operation is handled by separate contacts (vacuum switching cells).

1.4.2 Basic connection of tapped winding

The following diagram shows the common basic connections for the tapped winding. Please refer to the relevant technical data for the possible basic connections for the various on-load tap-changer types.

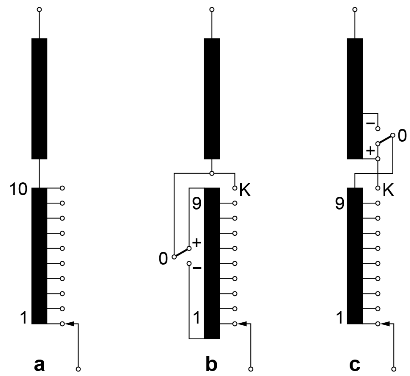


Figure 3: Basic connections

a	Without change-over selector
b	With reversing change-over selector
c	With coarse change-over selector

1.4.3 On-load tap-changer designations

Each type of on-load tap-changer is available in a number of models, offering a different number of phases, maximum rated through-current, highest voltage for equipment U_m, tap selector size and basic connection diagram. The designation of a particular on-load tap-changer model therefore depends on these features, hence ensuring an unmistakable and non-interchangeable on-load tap-changer designation.

1.4.3.1 Example of on-load tap-changer type designation

VACUTAP® VM® on-load tap-changer, single-phase, maximum rated through-current I_{um} = 650 A, highest voltage for equipment U_m = 123 kV, tap selector size B, tap selector in accordance with basic connection diagram 10191W.

Type designation	VACUTAP® VM® I 651-123/B-10191W
VACUTAP® VM®	On-load tap-changer type
I	Number of phases
651	Maximum rated through-current I_{um} in A and number of parallel main switching contacts (last digit) for single-phase on-load tap-changers
123	Highest voltage for equipment U_m (in kV)
B	Tap selector size
10191W	Basic connection diagram

Table 2: Example of designation of on-load tap-changer

1.4.3.2 Number of positions and basic connection diagram

The tap selector can be adapted to a large extent to the required number of positions and tapped winding circuit. The corresponding basic connection diagrams differ in terms of tap selector division, number of operating positions, number of mid-positions and change-over selector model.

Example: Tap selector division 10, maximum of 19 operating positions, 1 mid-position, change-over selector designed as reversing change-over selector

Designation of basic connection diagram	10191W
10	Contact circle pitch of tap selector
19	Maximum number of operating positions
1	Number of mid-positions
W	Change-over selector model (W=reversing change-over selector, G=coarse tap connection)

Table 3: Example of designation of basic connection diagram

1.4.3.3 Overview of on-load tap-changer types

The following table provides an overview for the various on-load tap-changer types in terms of number of phases, maximum rated through-currents I_{um}, highest voltages for equipment U_m and maximum number of operating positions.

On-load tap-changer type	Number of phases	maxi. I_{um} [A]	max. U_m [kV]	Number of max. operating positions	
				without change-over selector	with change-over selector
VACUTAP® VT®	I	500	40.5	9	-
VACUTAP® VV®	I, III	600	145	12	23
VACUTAP® VM®	II, III	650	300	22	35
	I	1,500	300	22	35
VACUTAP® VRC	III	700	245	18	35
	II	700	300	18	35
	I, I HD	1,300	300	18	35
VACUTAP® VRD	III	1,300	245	18	35
	I, I HD	1,300	300	18	35
VACUTAP® VRE	III	700	245	18	35
	I, I HD	1,300	300	18	35
VACUTAP® VRF	III	1,300	245	18	35
	I HD, II	1,300	362	18	35
	I	1,600[1)]	362	18	35
	I	2,600	362	18	35
VACUTAP® VRG	III	1,300	245	18	35
	I HD, II	1,300	362	18	35
	I	1,600[1)]	362	18	35
	I	2,600	362	18	35
OILTAP® V	III	350	123	14	27
	I	350	76	14	27
OILTAP® MS	I, II, III	300	245	14	27
OILTAP® M	II, III	600	245	22	35
	I	1,500	300	22	35
OILTAP® RM	III	600	300	18	35
	I	1,500	300	18	35
OILTAP® R	III	1,200	300	18	35
	I	3,000	300	18	35
OILTAP® G	III	1,600	300	16	31
	I	3,000	300	16	31

Table 4: On-load tap-changer types

[1)] VACUTAP® VRF I 1601 and VACUTAP® VRG I 1601 can be used with applications up to I_{um} = 1,600 A without enforced current splitting (parallel winding branch).

Refer to the technical data for the corresponding on-load tap-changer for further details and information about special models.

1.4.3.4 Adjustment position and mid-position

The adjustment position is the position in which the on-load tap-changer is supplied. During maintenance work (removal or installation of on-load tap-changer insert) the on-load tap-changer must be in the adjustment position. For further details, please refer to the corresponding operating and maintenance instructions. The adjustment position is explicitly indicated in each detailed connection diagram of the on-load tap-changer.

A distinction is made between circuits with 1 mid-position and 3 mid-positions. The mid-position (if there are 3, the central mid-position) is usually also the adjustment position (see detailed connection diagram of on-load tap-changer).

In the mid-position (if there are 3, the central mid-position), the "K" contact is live with the reversing change-over selector model or coarse tap design. Power does not flow through the tapped winding in this position. The change-over selector (reversing change-over selector or coarse change-over selector) can only be switched when in this position.

With 1 mid-position, tap-changes to positions immediately before and after the mid-position result in a change in voltage. With 3 mid-positions, there is no change in voltage between the mid-positions. Bridged contacts (see e.g. Parallel connection of tap selector planes chapter [▶ 51]) are not considered to be mid-positions.

1.4.3.5 Designation of tap selector connection contacts and operating positions

When an order is placed, a detailed connection diagram is produced for each on-load tap-changer. This is the only binding source of reference for the on-load tap-changer connection to the transformer.

Other than electrical connections, this detailed connection diagram contains a schematic illustration of the geometric arrangement of connection contacts viewed from above.

In this detailed connection diagram, the tap selector connection contacts and operating positions for the affected on-load tap-changers are designated as specified by the customer.

The contact designations used in dimensional drawings for on-load tap-changers always correspond to the normal version in accordance with MR standard.

The position designation of the on-load tap-changer is identical to that of the motor-drive unit.

Normal version in accordance with MR standard

When designating the connection contacts and operating positions in accordance with the MR standard, tap selector connection contact 1 is live in operating position 1. Operating position 1 is also the end position and is reached by moving counter-clockwise through the set range for tap selector contact bridge movement.

Example of basic connection diagram 10193W:

Position	19	18	17	...	11	10	9	...	3	2	1
Live tap selector connection contact	9	8	7	...	1	K	9	...	3	2	1
Change-over selector connecting		0-		→	0-	0-	0+	→		0+	
				←	0-	0+	0+	←			
Actuation following		→				"Raise"				→	
		←				"Lower"				←	
Hand crank direction of rotation	→					Clockwise				→	
	←					Counterclockwise				←	
Tap selector contact bridge	→					Counterclockwise				→	
	←					Clockwise				←	
Motor-drive unit control	→					By "K2" motor contactor				→	
	←					By "K1" motor contactor				←	

Table 5: Assignment of designations for normal version in accordance with MR standard taking the example of basic connection diagram 10193W

The following diagram shows the contact designation of the two tap selector planes from above with 1...9, K (clockwise).

The on-load tap-changer is in position 2, the change-over selector is connecting contacts 0 and +.

Position 1 is reached by operating the other tap selector contact bridge counter-clockwise (viewed from above), i.e. manually by turning the hand crank to the right (clockwise) or with a motor-drive unit by activating motor contactor K2.

The direction of rotation on the on-load tap-changer is retained regardless of the drive shaft arrangement selected.

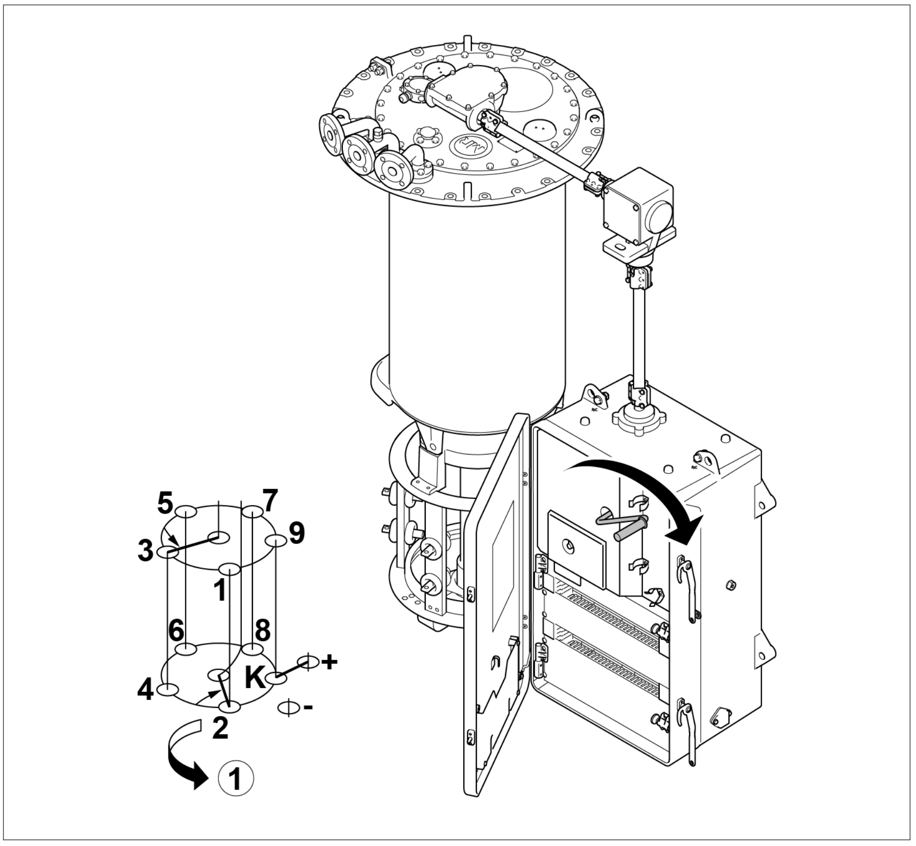


Figure 4: Directions of rotation for normal version in accordance with MR standard

1.5 Advanced retard switch function

1.5.1 ARS switching concept

An Advanced Retard Switch (ARS) is used to switch over a winding during transformer operation and basically has two operating positions. During an ARS operation the through-current is commutated from one current path to another current path with the same potential.

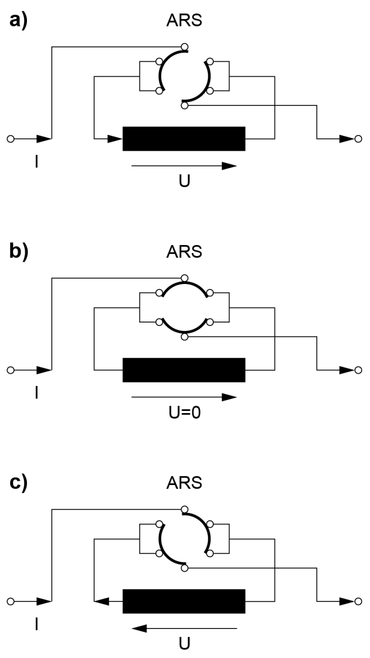


Figure 5: Advanced Retard Switch (ARS) for reversing the polarity of a winding

a)	ARS in operating position 1
b)	ARS during tap-change operation
c)	ARS in operating position 2

The ARS can be used for different applications in combination with an on-load tap-changer. The ARS is mainly used in applications with a large regulating range (e.g. phase shifter transformers) to switch the polarity of the tapped winding (double reversing change-over selector switching concept).

You can find more information in the technical data for the COMTAP® ARS.

1.5.2 ARS designations

Example	ARS I 1822 - 145 - 18 02 0 DW		
ARS	Product designation	ARS	COMTAP® ARS
I	Number of phases	I	Single-phase
		III	Three-phase
1822	Maximum rated through-current I_{um} and identification of necessary current splitting (3rddigit) and indication of parallel switching planes per phase (4th digit)	1000	1000 A
			No current splitting
			No parallel switching planes
		1822	1800 A
			Double current splitting
			2 parallel switching planes
		2433	2400 A
			Triple current splitting
			3 parallel switching planes
			Just single-phase
145	Highest voltage for equipment U_m	123	123 kV
		145	145 kV
		170	170 kV
18	Contact circle pitch	18	18 pitches, contact circle diameter 850 mm
02	Number of operating positions	02	2 operating positions
0	Number of mid-positions	0	No mid-position
DW	Type of tap-change operation	DW	Double reversing change-over selector

Table 6: Explanation of designations for advanced retard switch

1.6 Off-circuit tap-changer function

1.6.1 Switching concept and basic connections

The off-circuit tap-changer is changed over from one operating position to the next by rotating an insulating drive shaft. Off-circuit tap-changers can be operated with either a motor-drive unit or manual drive.

Special connections are possible in addition to the basic connections shown in the following diagram.

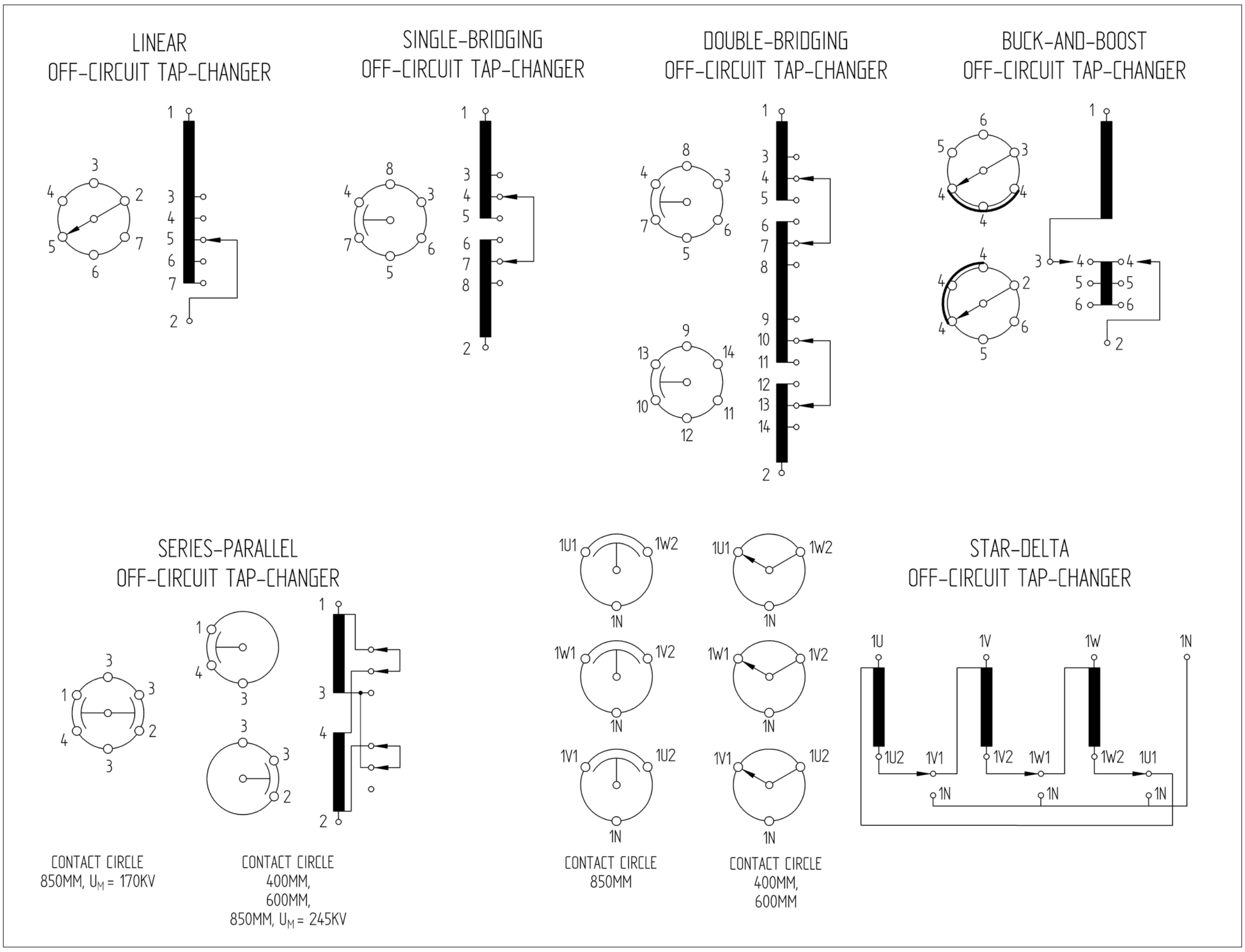


Figure 6: Basic connections for DEETAP® DU off-circuit tap-changer

Refer to the technical data for DEETAP® DU for further information.

1.6.2 Off-circuit tap-changer designations

Example:	DU III 1000 - 145 - 06 05 0 Y		
DU	Product designation	DU	DEETAP® DU
III	Number of phases	I	Single-phase
		III	Three-phase
1000	Maximum rated through-current I_{um}	200	200 A
		4XX	400 A
		600	600 A
		8XX	800 A
		1000	1000 A
		12X2	1200 A
		16X2	1600 A
		2022	2000 A
		I_{um} > 2000 A on request	
	Current splitting required	XX0X	No current splitting
		XX2X	Double current splitting
	Parallel switching planes	XXX0	None
		XXX2	2 per phase
145	Highest voltage for equipment U_m [kV]	36; 72.5; 123; 145; 170; 245	
		U_m > 245 kV on request	
06	Contact circle pitch	60	6 pitches (400 mm)
		12	12 pitches, (600 mm)
		18	18 pitches, (850 mm)
05	Number of operating positions	Depending on model, 2 to 17 operating positions are possible	
0	Number of mid-positions	0	No mid-position
		1	One mid-position
Y	Type of tap-change operation	Y	Linear off-circuit tap-changer for neutral application
		D	Linear off-circuit tap-changer for delta application
		ME	Single-bridging off-circuit tap-changer
		MD	Double-bridging off-circuit tap-changer
		SP	Series-parallel off-circuit tap-changer
		YD	Star-delta off-circuit tap-changer
		BB	Buck-and-boost off-circuit tap-changer
		S	Special connection

Table 7: Explanation of designations for off-circuit tap-changer

2 Electrical properties

This chapter contains general information about the electrical properties of on-load tap-changers, off-circuit tap-changers and Advanced Retard Switches (ARS).

More information about special applications can be found in the Applications [▶ 54] chapter.

2.1 Through-current, step voltage, step capacity

The through-current is the current which flows through the on-load tap-changer and off-circuit tap-changer under normal operating conditions. The level of an on-load tap-changer's through-current generally differs over the set voltage range (e.g. while the transformer's rated power remains constant).

Rated through-current I_u

The maximum through-current which a transformer can continuously carry must be used to rate the on-load tap-changer and off-circuit tap-changer. This maximum permitted continuous through-current of the transformer is the rated through-current I_u of the on-load tap-changer or off-circuit tap-changer.

Step voltage U_{st}

The step voltage is the operating voltage found between adjacent taps. The step voltage may remain constant or change over the entire set range. If the step voltage is variable, the transformer's maximum step voltage U_{st} is used to rate the on-load tap-changer and off-circuit tap-changer.

Maximum rated through-current I_{um}

The maximum rated through-current I_{um} is the maximum design-dependent through-current of an on-load tap-changer and off-circuit tap-changer to which the current-related type tests relate.

Rated step voltage U_i

The rated step voltage U_i of an on-load tap-changer is the highest step voltage permissible for one particular value of the rated through-current I_u. Together with a rated through-current, this is known as the associated rated step voltage.

Maximum rated step voltage U_{im}

The maximum rated step voltage U_{im} is the maximum permissible design-dependent step voltage of an on-load tap-changer or off-circuit tap-changer.

Transition resistors

The diverter switch's transition resistors are configured depending on the levels of maximum step voltage U_{st} and the rated through-current I_u of the transformer for which the on-load tap-changer is intended.

Since the permissible rated through-current I_u and permissible step voltage U_{st} depend on value of the transition resistors, the rated levels relate to the relevant application.

If an on-load tap-changer is operated with step voltage and through-current values other than those stated in the order, Maschinenfabrik Reinhausen GmbH (MR) must check whether this is possible. For example, if the transformer power is increased by means of improved cooling or the on-load tap-changer is used in a different transformer, the transition resistors may have to be adapted.

This also applies if the desired new rated values I_u and U_{st} are below the original values. The transition resistor configuration affects both the switching capacity loading of the contacts and the consistent contact wear.

Rated step capacity P_{StN}

The rated step capacity P_{StN} is the product of the rated through-current I_u and associated rated step voltage U_i:

$\mathbf{P_{StN} = I_u \times U_i}$

The following diagram shows the typical load limits of a diverter switch. This shows that the permissible operating range is limited by the maximum rated step voltage U_{im} and maximum rated through-current I_{um}.

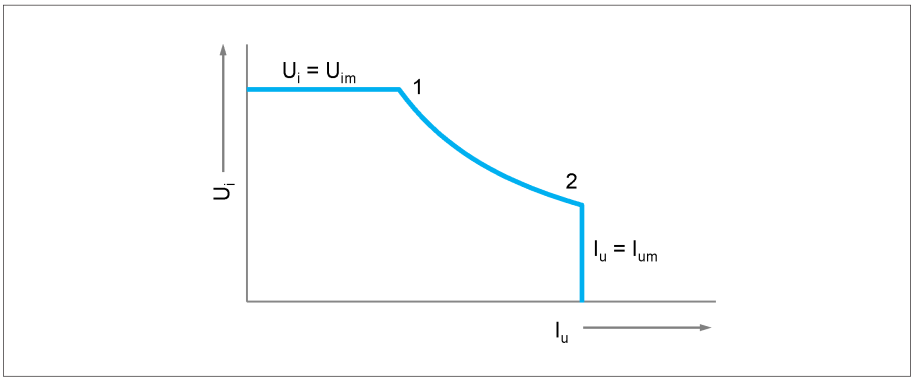


Figure 7: Rated step capacity diagram for diverter switch

1	Upper corner
2	Lower corner

The curve points between corners 1 and 2 are only provided by the permissible rated switching capacity. The permissible rated switching capacity between corners 1 and 2 corresponds to linked pairs of values for I_u and U_i and may be constant or variable.

The rated step capacity diagram and individual values for I_u and U_i in corners 1 and 2 are stated separately for each on-load tap-changer type (see technical data for relevant on-load tap-changer).

Limit step capacity and limit switching capacity

The limit step capacity is the largest step capacity which can be switched with certainty. In its standard model, each MR on-load tap-changer can switch at least twice the rated through-current I_u at the step voltage U_{st} for which the on-load tap-changer was configured. This limit switching capacity is proven by type testing in accordance with IEC 60214. Appropriate measures must be taken to prevent tap changes with currents of more than twice the rated through-current I_u.

2.2 Insulation

The insulation capacity of the various insulation distances and assignment of this to the voltages of the transformer windings are detailed in the technical data for the relevant on-load tap-changer, ARS or off-circuit tap-changer. The stated rated withstand voltages for the insulation arrangement apply to new, perfectly dried insulation in prepared transformer oil (at an ambient temperature of at least 10 °C).

The following details are needed to select an on-load tap-changer, ARS or off-circuit tap-changer:

- Maximum mains-frequency operating voltages
- Test AC voltages during transformer test
- Impulse voltages during transformer test (lightning surge, switching surge, wave isolated in back and wave isolated in front)

The transformer manufacturer is responsible for the correct choice of rated withstand voltages depending on insulation coordination at the operating site. The necessary rated withstand voltages should be observed for the various insulation distances:

- Insulation to ground
- With multi-phase types: Insulation between phases
- Insulation between a phase's contacts

The details required depend on the type of regulation (e.g. basic connection of tapped winding with on-load tap-changers) and the tap-changer type.

2.3 Leakage reactance with coarse tap selector connection

Only the leakage reactance of one tap is active for most of the on-load tap-changer's switching operations. This has very little impact on how the on-load tap-changer works.

However if a switch is made from the end of the coarse winding to the end of the tapped winding (or vice versa), all windings of the coarse and tapped windings lie between the selected and preselected taps. Although from an electrical standpoint the on-load tap-changer only switches a maximum of one tap, this produces considerably more leakage reactance for the switching circuit which acts as internal resistance of the step voltage. This increased leakage reactance causes a phase shift on the transition contacts of the on-load tap-changer between the breaking current and recovery voltage which may result in longer arc times.

In applications with a coarse winding positioned right next to the tapped winding, the active leakage reactance can be established using the short-circuit impedance of these two windings.

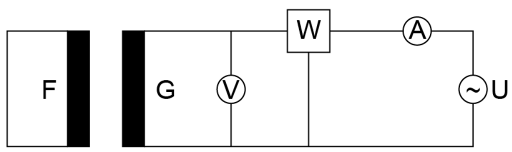


Figure 8: Determining leakage reactance

F	Tapped winding	G	Coarse winding
V	Voltmeter	W	Wattmeter
A	Ammeter	U	Supply voltage

One method of measurement in which the connection terminals can be reached via the diverter switch is shown in the following diagram.

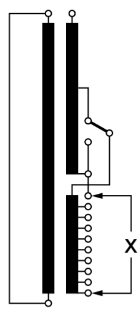


Figure 9: Leakage reactance with coarse tap selector connection

Analytical formulas for calculating the leakage reactance between two windings can also be used to calculate the leakage reactance between the coarse winding and tapped winding. For concentric winding arrangements, the accuracy of the calculated values is sufficient.

For applications with coarse taps which are not directly adjacent to the tapped winding (e.g. multiple coarse taps), all windings and their couplings must be used for the switching circuit analysis. All the calculations required can be undertaken by Maschinenfabrik Reinhausen GmbH (MR). The winding design and connection of all winding parts should be stated for this purpose. MR will provide the necessary form.

2.4 Tapped winding potential connection

2.4.1 Recovery voltage and breaking current

During its switching operation the tapped winding is briefly electrically isolated from the main winding by the reversing change-over selector or coarse change-over selector. It then adopts a potential resulting from the voltages of the adjacent windings and coupling capacities for these windings or earthed parts.

This potential shift of the tapped winding produces corresponding voltages between the deactivating change-over selector contacts because one contact is always connected to the tapped winding and the other contact is always connected to the main winding. This voltage is known as the recovery voltage U_W.

When separating the change-over selector contacts, a capacitive current has to be interrupted. This current depends on the aforementioned coupling capacities of the tapped winding. This current is known as the breaking current I_S.

The recovery voltage U_W and breaking current I_S may result in impermissible signs of discharge on the change-over selector. The permissible range of recovery voltage U_W and breaking current I_S for the different on-load tap-changer types can be seen in the following diagrams.

Without tie-in resistor (R, VRD and VRF with tap selector size C/D):

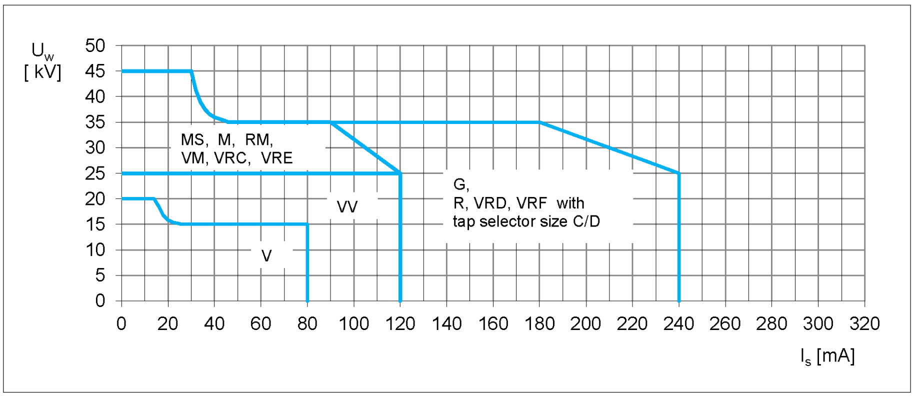


Figure 10: Approximate values for U_w and I_s **without** tie-in resistor R_P

U_W	Recovery voltage
I_S	Breaking current

Without tie-in resistor (R and VRG with tap selector size E):

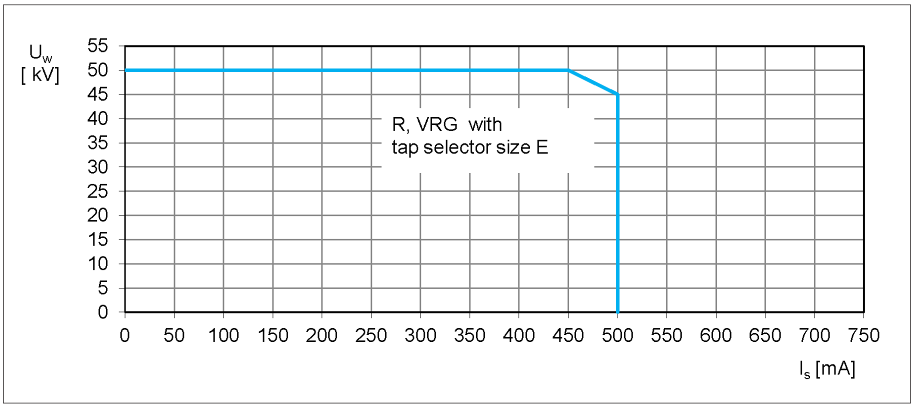


Figure 11: Approximate values for U_w and I_s **without** tie-in resistor R_P

If the calculations produce pairs of values for U_W and I_S which are outside the permissible range, the tapped winding must be connected during the switching process with a tie-in resistor. Possible tie-in measures are shown in the following diagram.

In connection a, the tapped winding is connected with an ohmic resistor R_P (tie-in resistor). In connection b, this tie-in resistor is only activated during the change-over selector's switching phase through the use of an additional potential switch S_P.

The design solutions for these tie-in measures differ depending on on-load tap-changer type. For more details, please refer to the technical data for the relevant on-load tap-changer.

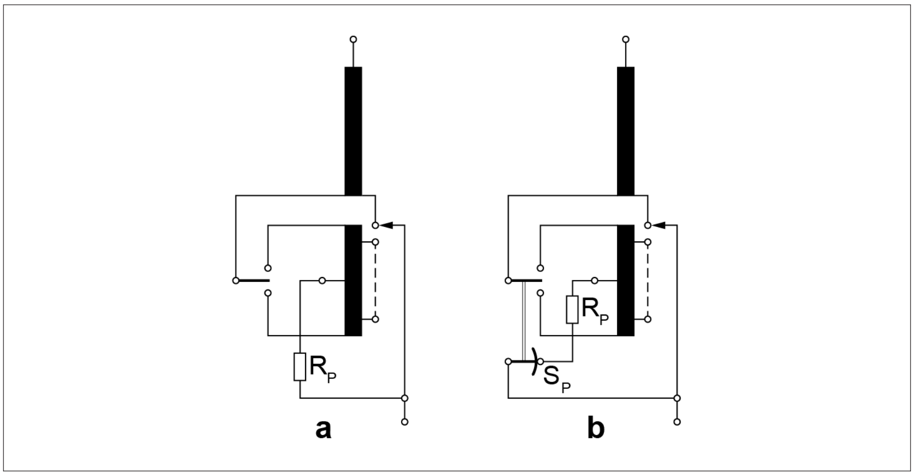


Figure 12: Potential connections (reversing change-over selector in mid-position)

a	With tie-in resistor R_P
b	With potential switch S_P and tie-in resistor R_P

The potential connection of the tapped winding with a tie-in resistor reduces the recovery voltage U_W at the change-over selector contacts, but the breaking current I_S is increased by the additional current through the tie-in resistor.

With tie-in resistor (R, VRD and VRF with tap selector size C/D):

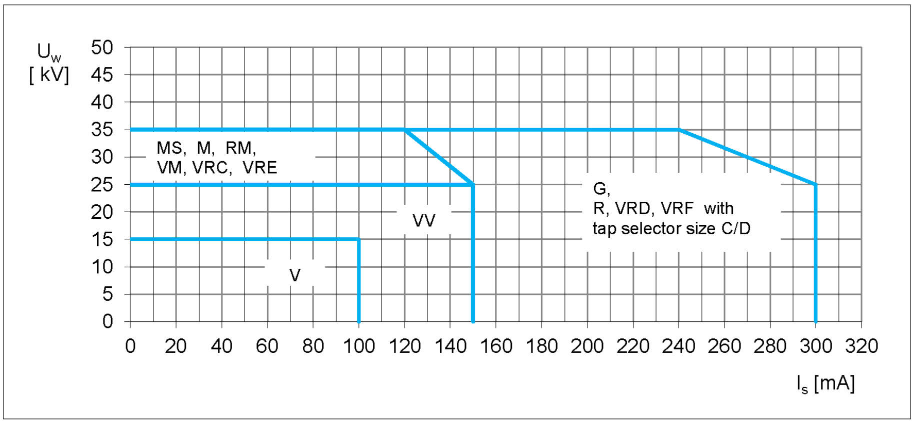


Figure 13: Approximate values for U_w and I_s **with** tie-in resistor R_P

U_W	Recovery voltage
I_S	Breaking current

With tie-in resistor (R and VRG with tap selector size E):

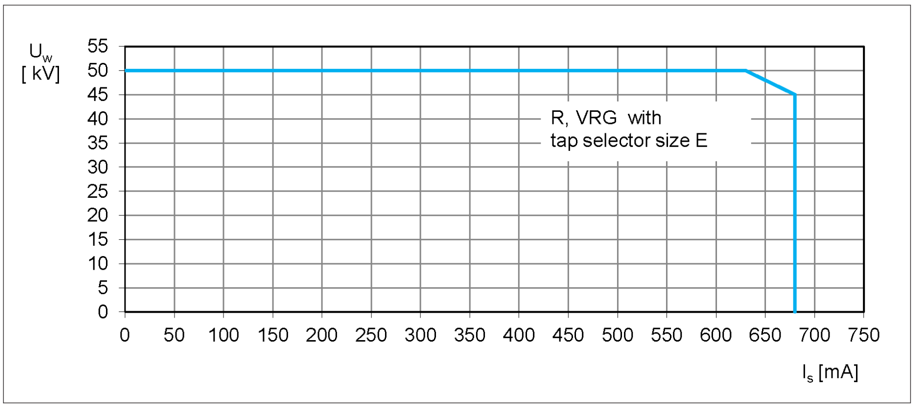


Figure 14: Approximate values for U_w and I_s **with** tie-in resistor R_P

The diagrams show the ranges of recovery voltage U_W and breaking current I_S for the different on-load tap-changer types which can be used with tie-in resistors without having to contact Maschinenfabrik Reinhausen GmbH (MR). This applies to cases where the breaking current I_S is determined mainly by the tie-in resistor. If the stated ranges are exceeded, the opinion of MR is needed.

Reducing the recovery voltage U_W by means of a tie-in resistor increases the breaking current I_S. For this reason, for winding arrangements with an unfavorable capacitive coupling there is not always a solution with a permissible change-over selector capacity.

In these cases, either a change-over selector with a higher permissible breaking current I_S has to be used or the winding arrangement has to be changed. The change-over selector capacity must therefore be checked in good time, especially for transformers with high ratings (i.e. large coupling capacities) and high operating voltages (i.e. large potential shift of tapped winding during change-over selector connection).

MR can calculate the recovery voltage U_W and breaking current I_s and configure any tie-in resistors needed. The following details are required:

- Winding arrangement, i.e. local position of tapped winding in relation to adjacent windings
- Capacity of tapped winding in relation to adjacent windings or capacity of tapped winding to earth or adjacent earthed windings
- AC voltage under operating conditions across windings or positions of windings adjacent to the tapped winding

The following details are also needed to size the tie-in equipment:

- Loads expected from lightning impulse voltage across the half tapped winding
- Operating and test AC voltage across the half tapped winding (generally apparent from the standard order details for the on-load tap-changer).

2.4.2 Snap-action contact

The snap-action contact is a concept for reducing the amount of gas produced during a change-over selector connection. The snap-action contact is used with tap selector size E when particular limit values are exceeded.

High loads on the change-over selector, caused by large breaking currents and large recovery voltages (typically e.g. in HVDC applications), result in the formation of more gas. Maschinenfabrik Reinhausen GmbH (MR) will calculate the volume of gas in such cases.

The snap-action contact can always be selected as an option. Use of the snap-action contact is recommended when average gas volumes of 7 ml and more are being created per change-over selector connection. The volume of gas can thereby be reduced by around 90%.

2.4.3 Sample potential connection calculation

Below is an example for the approximate calculation of recovery voltage on the change-over selector.

- On-load tap-changer combination:
  - VM I 301 / VM II 302 - 170 / B - 10 19 3W
- Transformer data:
  - Rated power 13 MVA
  - High voltage winding 132 kV ± 10 %
  - Delta connection, 50 Hz
  - Tapped winding in reversing change-over selector connection
  - Double concentric structure of high voltage winding with internal main winding (disk-type coils) and external tapped winding
  - Winding capacities

    C_1 = 1810 pF (between main winding and tapped winding)

    C_2 = 950 pF (between tapped winding and earth)

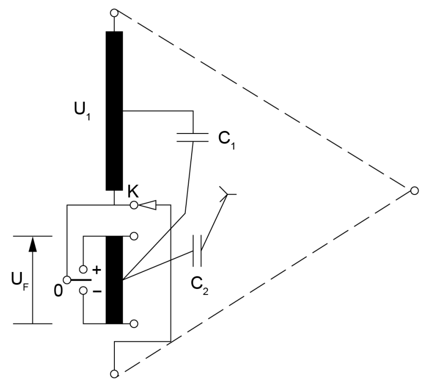


Figure 15: High voltage winding connection

U_1	High voltage winding voltage
U_F	Tapped winding voltage
C_1	Winding capacity between main winding and tapped winding
C_2	Winding capacity between tapped winding and earth

Assuming that the winding capacities C_1 and C_2 are both active in the winding center, the following is true for the recovery voltages U_{W+} and U_{W-}:

$$\vec{U}_{W+} = \frac{\vec{U}_1}{2} + U_{C1} + \frac{\vec{U}_F}{2}, \quad \vec{U}_{W-} = \frac{\vec{U}_1}{2} + U_{C1} - \frac{\vec{U}_F}{2}$$

and the voltage across C_1

$$\vec{U}_{C1} = j \cdot \frac{U_1}{2 \cdot \sqrt{3}} \cdot \frac{C_2}{C_1 + C_2}$$

and therefore as a vector variable and amount

$$\vec{U}_{W+} = \frac{U_1}{2} - j \cdot \frac{U_1}{2 \cdot \sqrt{3}} \cdot \frac{C_2}{C_1 + C_2} + \frac{U_F}{2}$$

$$|\vec{U}_{W+}| = \sqrt{\left(\frac{U_1}{2} + \frac{U_F}{2}\right)^2 + \left(\frac{U_1}{2 \cdot \sqrt{3}} \cdot \frac{C_2}{C_1 + C_2}\right)^2}$$

$$\vec{U}_{W-} = \frac{U_1}{2} - j \cdot \frac{U_1}{2 \cdot \sqrt{3}} \cdot \frac{C_2}{C_1 + C_2} - \frac{U_F}{2}$$

$$|\vec{U}_{W-}| = \sqrt{\left(\frac{U_1}{2} - \frac{U_F}{2}\right)^2 + \left(\frac{U_1}{2 \cdot \sqrt{3}} \cdot \frac{C_2}{C_1 + C_2}\right)^2}$$

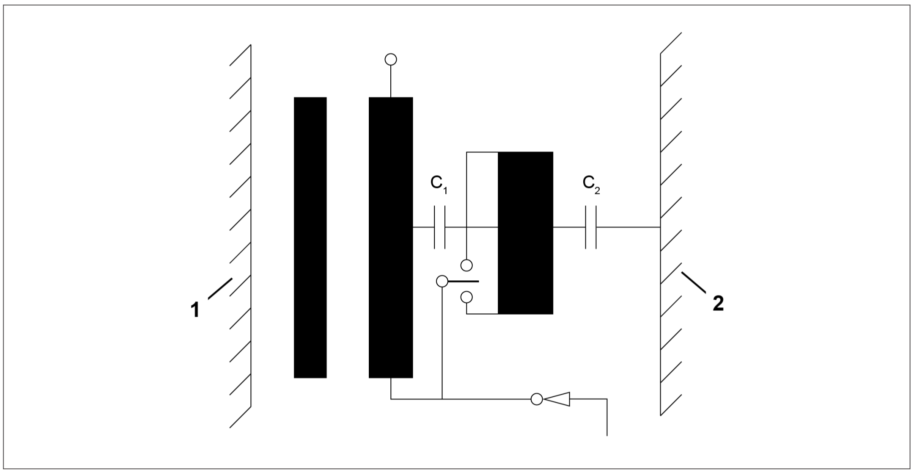


Figure 16: Winding arrangement with associated winding capacities

1	Transformer core	2	Transformer tank
C_1	Winding capacity between main winding and tapped winding		
C_2	Winding capacity between tapped winding and earth		

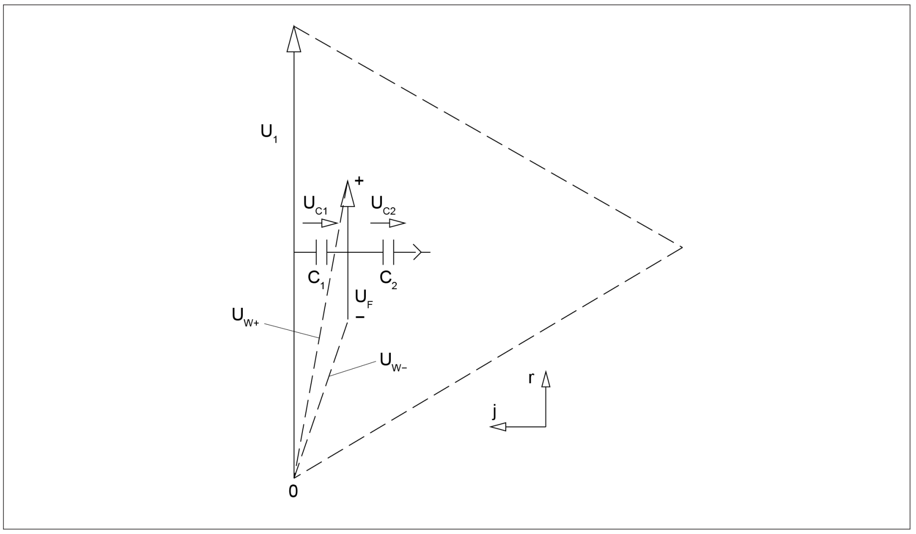


Figure 17: Diagram for calculating the recovery voltages at change-over selector contacts (+) and (-)

U_1	High voltage winding voltage
U_F	Tapped winding voltage
U_{W+}	Recovery voltage on change-over selector contact (+)
U_{W-}	Recovery voltage on change-over selector contact (-)
U_{C1}	Voltage drop at winding capacity C_1
U_{C2}	Voltage drop at winding capacity C_2

When C_1 = 1810 pF, C_2 = 950 pF, U_1 = 132 kV, U_F = 13.2 kV, the following values are calculated for the recovery voltages U_{W+} and U_{W-}:

$$|\vec{U}_{W+}| = \sqrt{\left(\frac{132\ kV}{2} + \frac{13{,}2\ kV}{2}\right)^2 + \left(\frac{132\ kV}{2 \cdot \sqrt{3}} \cdot \frac{950\ pF}{1810\ pF + 950\ pF}\right)^2} = 73{,}78\ kV$$

$$|\vec{U}_{W-}| = \sqrt{\left(\frac{132\ kV}{2} - \frac{13{,}2\ kV}{2}\right)^2 + \left(\frac{132\ kV}{2 \cdot \sqrt{3}} \cdot \frac{950\ pF}{1810\ pF + 950\ pF}\right)^2} = 60{,}83\ kV$$

The breaking currents I_{S+} and I_{S-} are:

$$I_{S+} = \frac{\vec{U}_1}{2 \cdot \sqrt{3}} \cdot \omega C_2 + j\ \frac{\vec{U}_1 + \vec{U}_F}{2} \cdot \omega\,(C_1 + C_2)$$

$$I_{S-} = \frac{\vec{U}_1}{2 \cdot \sqrt{3}} \cdot \omega C_2 + j\ \frac{\vec{U}_1 - \vec{U}_F}{2} \cdot \omega\,(C_1 + C_2)$$

The figures stated above result in:

I_{S+} = 63.97 mA

I_{S-} = 52.75 mA

A tie-in resistor is needed because of the high values for U_W.

Fitting a tie-in resistor R_P = 235 kΩ results in:

U_{W+} = 17.11 kV

U_{W-} = 12.47 kV

I_{S+} = 74.29 mA

I_{S-} = 54.15 mA

2.5 Overload

2.5.1 Through-currents greater than the rated through-current

MR on-load tap-changers and off-circuit tap-changers are suitable for all loadings of the transformer in accordance with IEC 60076-7:2005 "Loading guide for oil-immersed power transformers".

IEC 60076-7 distinguishes between three types of operation:

- Normal cyclic loading
- Long-time emergency loading
- Short-time emergency loading

The suitability of on-load tap-changers and off-circuit tap-changers for the above types of power transformer operation is proven by type testing in accordance with IEC 60214-1:2003.

MR on-load tap-changers and off-circuit tap-changers are also suited to all transformer loads in accordance with IEEE Std C57.91™-2011 "IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage-Regulators" with the following exception: Overload requirement greater than 200%.

Overload requirementsgreater than 200% may arise, e.g. for the "Short time emergency loading" type of operation with distributor transformers and must be stated in the query.

IEEE C57.91 distinguishes between four types of operation:

- Normal life expectancy loading
- Planned loading beyond nameplate rating
- Long-time emergency loading
- Short-time emergency loading

When operating with "normal cyclic loading" or "normal life expectancy loading", through-currents greater than the rated through-current may arise during a daily load cycle. If the operating conditions stated in IEC 60076-7 and IEEE C57.91 (duration and level of power during one daily cycle, transformer oil temperature etc.) are observed, this is not considered extraordinary loading but normal operation. Therefore, for the types of operation stated, particular consideration does not have to be given to the possible brief instances of through-currents greater than the rated through-current when selecting the on-load tap-changer.

2.5.2 Operation under varying operating conditions

If a transformer is operated under varying operating conditions with varying power levels (e.g. increased transformer power due to type of cooling or ambient temperature), note the following:

The rated through-current required for an on-load tap-changer must be based on the maximum transformer power as the rated power; see also IEC 60076-1:2011.

This is necessary because, due to increased power, the transformer's oil temperature is not reduced despite increased transformer cooling and therefore, contrary to the transformer, the external operating conditions of the on-load tap-changer are not improved.

It is also necessary because the transition resistors of the on-load tap-changers are designed on the basis of the maximum through-current in order to limit the switching capacity loading on the on-load tap-changer contacts to permissible values.

2.5.3 Details needed for queries relating to overload conditions

When making queries relating to overload conditions, a definition with reference to the above types of operation is needed to avoid misunderstanding. The operating conditions must be described clearly.

In the event of types of operation which cannot be defined by reference to IEC 60076-7:2005 or IEEE Std C57.91™-2011, the following details are needed:

- Through-currents and associated loading duration during one daily cycle
- Oil temperature of the transformer during one daily cycle
- Expected number of tap-change operations during loading phases of one daily cycle (for on-load tap-changer only)
- Duration of overload operation in days/weeks/months
- Frequency of overload operation, e.g. "once a year" or "rarely, only if other transformers fail".

2.6 On-load tap-changer and off-circuit tap-changer loading from short-circuits

The permissible loading from short-circuits is given by:

- Rated short-time current as effective value of permissible short-circuit current
- Rated peak withstand current as highest permissible peak value of short-circuit current
- Rated duration of short-circuits as permissible short-circuit duration when loaded with rated short-time current

All MR on-load tap-changers and off-circuit tap-changers at least satisfy the requirements of IEC 60214-1:2003 in terms of short-circuit strength. The permissible short-circuit duration when loaded with short-time currents lower than the rated short-time current or the permissible short-time current for durations longer than the rated duration of short-circuits can be calculated using the following equation:

$$I_x^2 \cdot t_x = I_K^2 \cdot t_K$$

I_K	Rated short-time current
t_K	Rated duration of short-circuits

I_x	Permissible short-time current during short-circuit duration t_x (where t_x is always greater than t_k)
t_x	Permissible short-circuit duration during loading with I_x (where I_x is always less than I_k)

Given that the dynamic loading is determined solely by the peak current, a peak current greater than the rated peak withstand current is not permitted. The rated values cannot therefore be converted to higher peak currents and short-time currents over a shorter short-circuit duration!

Short-circuit loads normally only occur very rarely when operating a transformer. This must be taken into account for applications with very frequent short-circuit loads - e.g. special test transformers - by selecting an on-load tap-changer with increased resistance to short-circuits. Details about the level and frequency of short-circuit loads expected are needed for this purpose.

2.7 Enforced current splitting

With single-phase on-load tap-changers and off-circuit tap-changers for large rated through-currents, current paths are switched in parallel. A distinction is made here between applications with and without "enforced current splitting". Applications with and without "enforced current splitting" with the same rated through-current require different on-load tap-changer and off-circuit tap-changer models.

Parallel contacts must not be bridged in arrangements with enforced current splitting. The voltage between parallel tapped windings must be noted when loaded with impulse voltage. The transformer manufacturer must state the resistance to impulse voltage required between the parallel tapped windings.

The significance of "enforced current splitting" is different for on-load tap-changers and off-circuit tap-changers:

On-load tap-changers:

During diverter switch operation, equal current splitting on the parallel contacts must be ensured. This requires a split tapped winding **and** a split main winding in every case. The leakage impedance between the parallel main windings must be at least three times the transition resistance of the on-load tap-changer.

Maschinenfabrik Reinhausen GmbH (MR) must be contacted to discuss such applications. A sketch of the complete winding arrangement with all parallel winding parts is required for this purpose.

Off-circuit tap-changers:

The tapped winding must be fully split. Several windings of the main winding connecting to the tapped winding must also be split.

2.8 Permissible overexcitation

MR on-load tap-changers satisfy the requirements of IEC 60076-1:2011 (5 % overexcitation) and IEEE Std C57.12.00™-2010 (10 % overexcitation).

2.9 Multi-column on-load tap-changers

Multi-column on-load tap-changers (e.g. 3 x VRC I) do not switch in synch, regardless of whether they are operated by one or more motor-drive units.

A tap offset may result in impermissibly high circulating currents which are only limited by the impedance of this current circuit. Superimposing these circulating currents with the load current impacts on the load of the on-load tap-changer which performs the last tap change.

In all applications in which circulating currents may arise due to asynchronous operation of multi-column on-load tap-changers, the transformer manufacturer must state the maximum circulating current. Maschinenfabrik Reinhausen GmbH (MR) can therefore take into account the increased switching capacity when selecting the on-load tap-changer and configuring the transition resistors (see also IEC 60214-2, Section 6.2.8).

3 Insulating oils

3.1 Mineral oil

When filling on-load tap-changer oil compartment and its oil conservator, use only new mineral insulating oil for transformers in accordance with IEC 60296 (Specification for unused mineral insulating oils for transformers and switchgear).

3.2 Alternative insulating liquids

Many MR on-load tap-changers and off-circuit tap-changers can also be operated with alternative insulating liquids.

Depending on the on-load tap-changer type or off-circuit tap-changer type and the insulating liquid, restricted operating conditions may however apply (e.g. with regard to test voltages or permissible temperature range). If you require more details of these restrictions, please contact Maschinenfabrik Reinhausen GmbH (MR).

The table below shows the insulating liquids approved for the types of operation.

Highly molecular hydrocarbons

Type of OLTC / OCTC	BETA-Fluid MICTRANS-G
VACUTAP® VV® VACUTAP® VRC VACUTAP® VRE	possible
OILTAP® V OILTAP® M OILTAP® RM	possible, but mineral oil is specified for the on-load tap-changer oil compartment by IEC 60296
DEETAP® DU	on request

Table 8: On-load tap-changers and off-circuit tap-changers for highly molecular hydrocarbons

Synthetic esters

Type of OLTC / OCTC	Synthetic esters in accordance with IEC 61099 (e.g. MIDEL 7131, ENVIROTEMP 200)
VACUTAP® VV® VACUTAP® VM® (does not apply to VM300) VACUTAP® VRC VACUTAP® VRE	possible
OILTAP® V OILTAP® M OILTAP® RM	possible, but mineral oil is specified for the on-load tap-changer oil compartment by IEC 60296
DEETAP® DU	on request

Table 9: On-load tap-changers and off-circuit tap-changers for synthetic esters

Natural esters

Type of OLTC / OCTC	ENVIROTEMP FR3 BIOTEMP
VACUTAP® VV® VACUTAP® VM® (does not apply to VM300) VACUTAP® VRC VACUTAP® VRE	possible
OILTAP® V OILTAP® M OILTAP® RM	possible, but mineral oil is specified for the on-load tap-changer oil compartment by IEC 60296
DEETAP® DU	on request

Table 10: On-load tap-changers and off-circuit tap-changers for natural esters

Silicone oils

Type of OLTC / OCTC	all permissible silicone oils for transformers
OILTAP® V	on request, but mineral oil is specified for the on-load tap-changer oil compartment by IEC 60296.
DEETAP® DU	on request

Table 11: On-load tap-changers and off-circuit tap-changers for silicone oils

4 Mechanical and design properties

This chapter contains general information about the mechanical and design properties of on-load tap-changers, off-circuit tap-changers and Advanced Retard Switches (ARS).

More information about special applications can be found in the Applications [▶ 54] chapter.

4.1 Temperatures

Please contact Maschinenfabrik Reinhausen GmbH (MR) for temperatures outside the stated ranges or in the event of deviations from the stated operating conditions.

You will find the permitted temperatures for drying in the product-specific assembly instructions or operating instructions.

4.1.1 Permissible temperature range for operation

With oil-insulated products, the temperature details relate to use of mineral oil in accordance with IEC 60296.

Customers are asked to specify the ambient temperature of the transformer, i.e. the air temperature, in the order details. All MR products are available for use at an ambient air temperature of - 25 °C to + 50 °C.

- 25 °C is also the lower oil temperature limit for applications with oil transformers. The upper limit value for the oil temperature is determined by the defined operating conditions in IEC 60214-1. The following MR products can be used up to a maximum transformer oil temperature of 115 °C even if the transformer is temporarily overloaded:

Product	$T_{min(oil)}$	$T_{max(oil)}$
VACUTAP® VV®, VM®, VR®	- 25 °C	115 °C
OILTAP® G, M, MS, R, RM, V	- 25 °C	115 °C
DEETAP® DU, COMTAP® ARS	- 25 °C	115 °C

Table 12: Permissible operating temperature range

The VACUTAP® VT® on-load tap-changer, which is used for dry-type transformers, can be operated up to a maximum ambient air temperature of 65 °C.

The ambient air temperature is crucial for products not installed in the transformer:

Product	$T_{min(air)}$	$T_{max(air)}$
TAPMOTION® ED motor-drive unit	- 25 °C	50 °C
Manual drive TAPMOTION® DD	- 45 °C	70 °C
Drive shaft	- 25 °C	80 °C
Protective relay RS2001	- 25 °C	50 °C

Product	$T_{min(air)}$	$T_{max(air)}$
OF100 oil filter unit, standard model	0 °C	80 °C
OF 100 oil filter unit	- 25 °C	80 °C

Table 13: Permissible operating temperature range

For special models (e.g. EX protection variants), please contact Maschinenfabrik Reinhausen GmbH (MR).

4.1.2 Permissible temperature range for storage and transport

A lower ambient temperature limit of - 40 °C applies to the transport and storage of all products with the following exceptions:

Product	Lower limit value
VACUTAP® VT®	Minimum - 25 °C
TAPMOTION® ED motor-drive unit with electronic components	Minimum - 25 °C
DEETAP® DU	Minimum - 45 °C
Manual drive TAPMOTION® DD	Minimum - 45 °C

Table 14: Exceptions for storage temperature limit

The maximum air ambient temperatures stated for operation apply for the upper limit value.

Exception: The upper storage and transport limit value for the TAPMOTION® ED motor-drive unit is 70 °C.

4.1.3 Arctic operation

Use at temperatures below - 25 °C is known as Arctic operation. A corresponding special model is available for the following on-load tap-changers:

Product	$T_{min(oil)}$	Restrictions
VACUTAP® VV® VACUTAP® VM® VACUTAP® VR®	- 40 °C	▪ Only permitted with normal motor runtime ▪ Only permitted when using LUMINOL™ TR/TRi mineral oil for transformers and on-load tap-changers
OILTAP® M, MS OILTAP® R, RM	- 40 °C	▪ Only permitted with normal motor runtime
OILTAP® V	- 40 °C	▪ At less than - 25 °C only rigid operation is permitted (no switching operations)

Table 15: Arctic model on-load tap-changer

At ambient temperatures of less than - 25 °C, a thermostat is provided to increase operating reliability. The thermostat comprises a thermo-sensor and measuring amplifier. The thermo-sensor is fitted in the on-load tap-changer head cover and records the temperature of the on-load tap-changer oil. In the control circuit, the measuring amplifier ensures that the motor-drive unit is blocked for electrical operation when the thermostat is activated.

In addition to on-load tap-changers, you can also receive the following products which are suited to Arctic operation (sometimes under particular conditions):

Product	$T_{min(oil)}$	Restrictions/comments
DEETAP® DU COMTAP® ARS	- 45 °C	▪ Standard model ▪ At less than - 25 °C only rigid operation is permitted (no switching operations)

Table 16: Other products for Arctic operation (oil surroundings)

Product	$T_{min(air)}$	Restrictions/comments
TAPMOTION® ED motor-drive unit	- 40 °C	▪ Arctic model
Manual drive TAPMOTION® DD	- 45 °C	▪ Standard model
Drive shaft	- 40 °C	▪ Arctic model
Protective relay RS2001	- 40 °C	▪ Standard model

Table 17: Other products for Arctic operation (air surroundings)

4.2 Permissible pressure loading

Pressure loading may result from underpressure and overpressure. Excess pressure loading may result in leaks and malfunctions.

This chapter contains information about preventive measures and the most important protective devices. The Oil conservator for the on-load tap-changer oil [▶ 44] chapter contains additional information about the height at which the oil conservator may be installed.

4.2.1 Pressure loading during oil filling and transport

After drying, the diverter switch oil compartment (diverter switch insert fitted) must be filled completely with oil again as soon as possible so that an impermissible amount of humidity is not absorbed from the surroundings. Diverter switch oil compartment and transformer are simultaneously filled with new transformer oil under vacuum.

During oil filling, a connecting lead must be installed between connections E2 and Q for evacuating in order to simultaneously apply vacuum to diverter switch oil compartment and transformer. The head and cover of the on-load tap-changer and off-circuit tap-changer are vacuum-resistant.

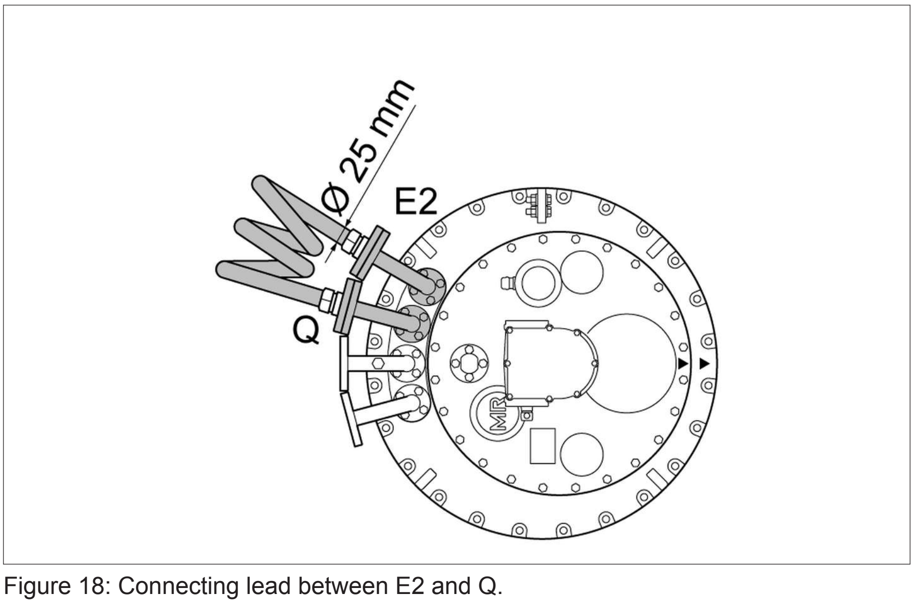


Figure 18: Connecting lead between E2 and Q.

Also if the transformer is filled with oil but stored or transported without an oil conservator, a connecting lead for pressure compensation must be installed between the interior of the compartment and the transformer tank's oil chamber. For more information on oil filling and transport, consult the relevant operating instructions.

4.2.2 Pressure loading during operation

The on-load tap-changer oil compartment is pressure-resistant to 0.3 bar of continuous differential pressure (test pressure 0.6 bar). The head and cover of the on-load tap-changer and off-circuit tap-changer are vacuum-resistant.

To reduce the consequences of an internal error in the on-load tap-changer, at least one protective device must be provided in acc. with IEC 60214-1.

Pressure relief device

The on-load tap-changer head covers of the MR on-load tap-changers are fitted with a rupture disk. This serves as the desired failure point for pressure relief if a pressure relief device is not used. Pressure relief devices reduce internal overpressure resulting from an internal error.

The MPreC® pressure relief device is secured onto a flange on a special on-load tap-changer head cover. It comprises a housing and a sealing flap subject to spring tension with signaling contacts.

The MPreC® pressure relief device and additional protective devices must be included in the circuit breaker's tripping circuit. When the protective device is tripped, the transformer must be immediately de-energized by the circuit breaker.

When the device's permissible tripping pressure is exceeded, the cover lifts up and the seal opens. When pressure falls below the tripping level, the device closes again. The installation height of the oil conservator must be taken into account when designing pressure relief devices.

Oil flow-controlled relay

The RS 2001 protective relay is tripped when the specified speed of oil flow from the on-load tap-changer head to the oil conservator is exceeded due to a fault. The flowing oil actuates the flap valve which tips over into position OFF. A contact is thereby actuated which trips the circuit breaker and de-energizes the transformer. The protective relay can be supplied as normally closed or normally open with one or more main switching contacts.

The RS protective relay and additional protective devices must be included in the circuit breaker's tripping circuit. When the protective device is tripped, the transformer must be immediately de-energized by the circuit breaker.

Additional information about the oil flow-controlled relay can be found in the RS protective relay [▶ 65] chapter.

For more information about the protective devices, consult the product-specific technical files or go to the REINHAUSEN corporate website: www.reinhausen.com.

4.3 Oil conservator for on-load tap-changer oil

This chapter describes the special conditions for on-load tap-changers which need to be taken into account for the oil conservator's installation height, sizing and drying unit.

The hydrostatic pressure of the insulating oil may restrict function and seal integrity if the installation height limits are not complied with. More information about pressure can be found in the Permissible pressure loading [▶ 42] chapter.

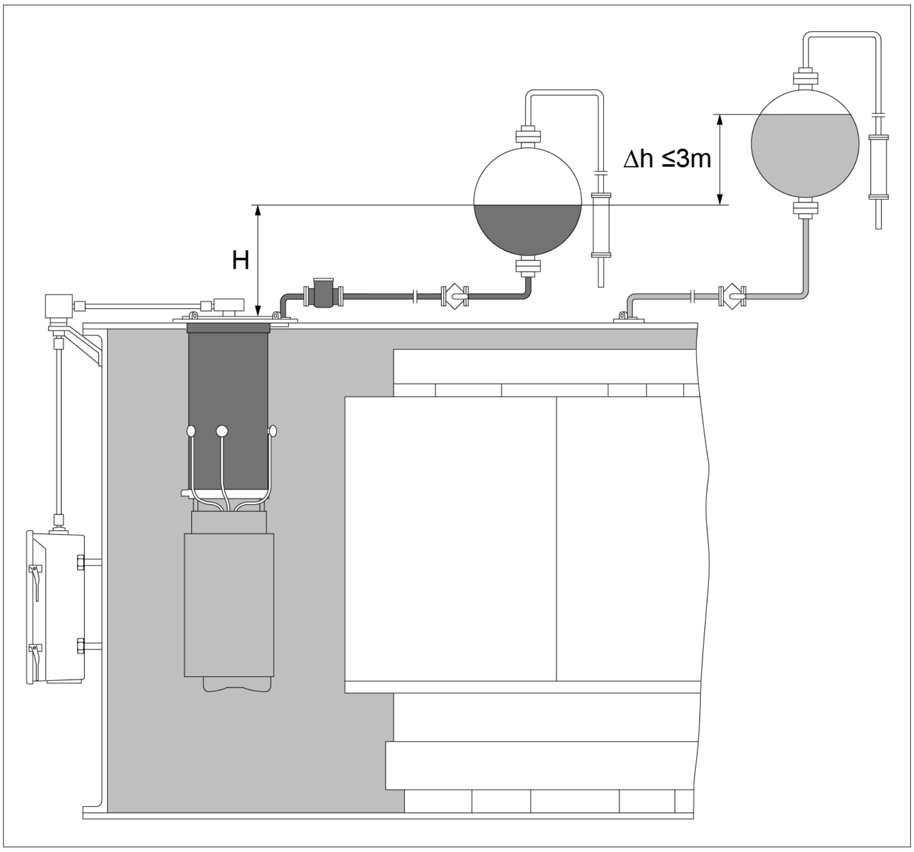


Figure 19: Overview of oil supply

Δh	Difference in height between oil levels in oil conservators
H	Height of oil level in on-load tap-changer's oil conservator above the on-load tap-changer head cover

4.3.1 Height of the oil conservator

The permissible heights for the oil conservators of the on-load tap-changer and transformer must be observed. These ensure:

- seal integrity of on-load tap-changer oil compartment in relation to surroundings and transformer
- correct function (e.g. switching process) of on-load tap-changer and other pressure-dependent devices

The standard on-load tap-changer model is designed for a maximum oil conservator height H_{max} of **up to 5 m**. To calculate this height, the distance between the maximum oil level in the oil conservator and the top edge of the on-load tap-changer head cover must be determined.

If the height H_{max} of the oil level in the on-load tap-changer's oil conservator is more than 5 m above the on-load tap-changer head cover, this must be stated in the order so that an appropriate product variant can be selected.

For VACUTAP® on-load tap-changers at installation heights H_{NHN} of more than 2,000 m above sea level, the maximum permissible height H_{max} of the oil conservator is increased by the minimum distance H_{max} between the oil level and on-load tap-changer head cover in accordance with section Installation height above sea level [▶ 45].

Difference in height Δh between oil levels in on-load tap-changer and transformer

If the oil conservators for the on-load tap-changer and transformer are in separate locations, the difference in height Δh between the oil levels may be a **maximum of 3 m**.

If the on-load tap-changer and transformer share an oil conservator (with or without divider), this difference is not normally reached. With a shared oil conservator, the difference in height can then be ignored.

4.3.2 Installation height above sea level

Air-insulated on-load tap-changer

Air-insulated on-load tap-changers are released without limitations up to an installation height H_{NHN} of 1,000 m above sea level.

OILTAP® oil-insulated on-load tap-changer

OILTAP® oil-insulated on-load tap-changers with an open oil conservator are released without limitations up to an installation height H_{NHN} of 4,000 m above sea level.

VACUTAP® oil-insulated on-load tap-changer

VACUTAP® oil-insulated on-load tap-changers with an open oil conservator are released without limitations up to an installation height H_{NHN} of 2,000 m above sea level. Above 2,000 m, a minimum height must be observed for the oil conservator.

The installation height of the oil conservator is determined by the distance H_{min} between the upper edge of the on-load tap-changer head cover and the oil level in the oil conservator.

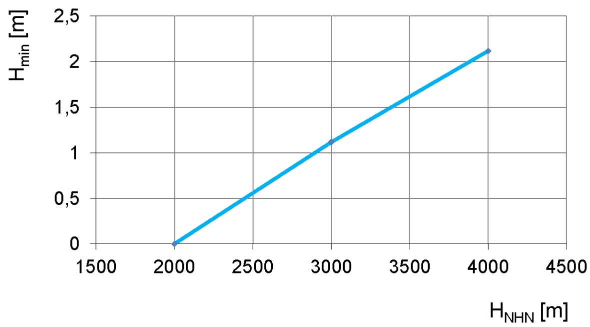


Figure 20: Minimum distance H_{min} between oil level and on-load tap-changer head cover

H_{min}	Distance between oil level in the oil conservator and upper edge of the on-load tap-changer head cover.
H_{NHN}	Installation height above sea level

For VACUTAP® on-load tap-changers at installation heights H_{NHN} of more than 2,000 m above sea level, the maximum permissible height of the oil conservator (in accordance with section Height of oil conservator [▶ 45]) is increased by this minimum distance H_{min} between the oil level and on-load tap-changer head cover.

Example:

For an installation height H_{NHN} of 2,500 m above sea level, the maximum permissible height H_{max} of the oil conservator is as follows:

$H_{max(2500m)} = H_{max(0m)} + H_{min} = 5\text{ m} + 0.5\text{ m} = 5.5\text{ m}.$

For installation heights H_{NHN} of more than 4,000 m or other applications, e.g. hermetic sealing, please contact Maschinenfabrik Reinhausen GmbH (MR).

4.3.3 Minimum oil conservator volume

The maximum expansion of the on-load tap-changer oil must be taken into account when sizing. This provides the useable volume required that must be available inside the oil conservator.

The recommended values are based on the following conditions:

- Mineral oil for transformers as per IEC 60296 (Specification for unused mineral insulating oils for transformers and switchgear) is used as the insulating medium.
- Calculations are based on an expansion coefficient of $\gamma = 0.0008\ K^{-1}$ for the mineral oil. This is a greater tolerance than has been used in the past.
- The temperature range of the surrounding transformer oil extends from – 25 °C to + 105 °C and with overload up to + 115 °C in accordance with IEC 60214-1.

If the on-load tap-changer is approved for temperatures of down to - 40 °C, an addition of around 10 % must be taken into account for the maximum oil expansion volume and for the minimum fill volume.

The entire oil volume in the on-load tap-changer's oil supply must be taken into account for the oil fill. The stated minimum fill volume within the on-load tap-changer oil compartment is part of this and relates to oil expansion at 20 °C.

The total oil volume is the sum of the following individual volumes:

1. Oil volume of on-load tap-changer oil compartment in accordance with product-specific technical data
2. Fill volume of pipes to oil conservator of on-load tap-changer
3. Fill volume of sump in oil conservator of on-load tap-changer
4. Plus minimum fill volume shown in the following table
5. The volumes involved in taking oil samples must also be taken into account. 2 oil samples of 10 l each are realistic for example.

Type of on-load tap-changer	U_m [kV]	Minimum useable volume [dm³]	Minimum fill volume at 20 °C [dm³]
VACUTAP® VV III	40-145	45	13
VACUTAP® VV I	76-145	23	6
VACUTAP® VM®	72.5-123	23	6
VACUTAP® VM®	170-300	30	9
VACUTAP® VR®	72.5-170	30	9
VACUTAP® VR®	245	35	10
VACUTAP® VR®	300-362	40	11
OILTAP® V III…Y	200-350	21	6
OILTAP® V III…D	200-350	27	8
OILTAP® V I	350	15	4

Type of on-load tap-changer	U_m [kV]	Minimum useable volume [dm³]	Minimum fill volume at 20 °C [dm³]
OILTAP® M/MS	72.5-170	25	7
OILTAP® M/MS	245	30	9
OILTAP® R/RM	72.5-170	30	8
OILTAP® R/RM	245-300	35	10
OILTAP® G	72.5-245	200	35
OILTAP® G	300-362	220	45

Table 18: Minimum useable volume and minimum fill volume of oil conservator of on-load tap-changer

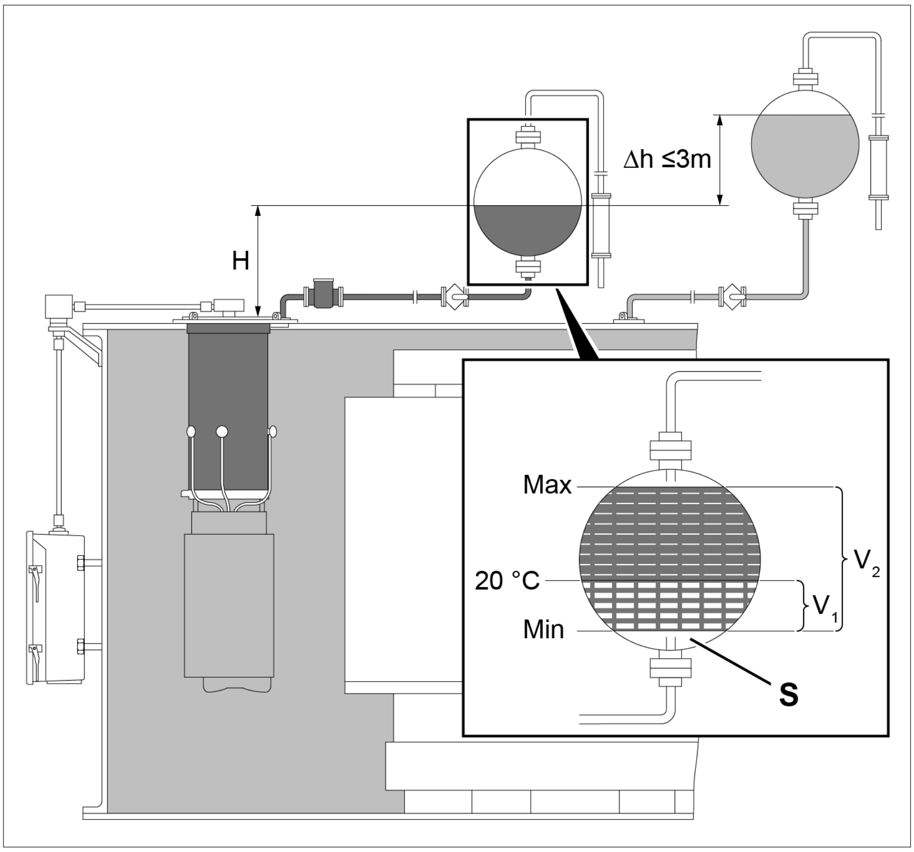


Figure 21: Expansion volume and minimum fill volume

S	Sump in oil conservator
V_1	Minimum fill volume in oil conservator at 20 °C
V_2	Expansion volume of on-load tap-changer oil = minimum useable volume of oil conservator

4.3.4 Drying unit for on-load tap-changer oil

Once the oil volume in the on-load tap-changer oil compartment changes, air is exchanged between the conservator and its surroundings (except with hermetic sealing applications). The connection between the air above the oil level in the conservator and the surrounding air is usually established using a drying unit which removes moisture from the incoming ambient air.

A spent drying unit can therefore result in an increase in the amount of water in the insulating oil and therefore a reduction in insulation strength.

The following criteria are important to drying unit sizing:

- Capacity of desiccant for absorbing moisture
- Thickness of layer of unused desiccant
- Frequency of switching operations
- Environmental conditions

The following assumptions are made when calculating approximate consumption volumes:

- The desiccant used is silica gel (orange). The capacity for absorbing moisture is around 35 percent by weight.
- Assuming a common drying unit geometry, the thickness of the layer of unused silica gel must be more than 5 cm at all times in order to reliably ensure that the incoming air is dried.
- The frequency of switching operations is based on three different values
  - 2,000 tap changes a year (e.g. network application with low number of tap-change operations)
  - 10,000 tap changes a year (e.g. network application with high number of tap-change operations)
  - 250,000 tap changes a year (e.g. industrial furnace application)
- Assuming a high average relative air humidity of around 70 %, the absolute air humidity in temperate climate zones is around 12.6 g/m³ and in humid tropical climate zones around 36.4 g/m³.

These assumptions provide the annual amount of silica gel required (including reserve drying unit).

For regions with a temperate climate:

On-load tap-changer	Number of tap change operations a year		
Type	**2,000**	**10,000**	**250,000**
VACUTAP® VV® VACUTAP® VM® OILTAP® V OILTAP® MS OILTAP® M	0.5	0.5	1.1

On-load tap-changer	Number of tap change operations a year		
Type	2,000	10,000	250,000
VACUTAP® VR® OILTAP® RM OILTAP® R	0.5	0.6	2.5
OILTAP® G	0.9	1.0	3.5

Table 19: Temperate climate: Annual drying unit demand in kg

For regions with a humid tropical climate:

On-load tap-changer	Number of tap change operations a year		
Type	2,000	10,000	250,000
VACUTAP® VV® VACUTAP® VM® OILTAP® V OILTAP® MS OILTAP® M	0.7	0.8	2.4
VACUTAP® VR® OILTAP® RM OILTAP® R	0.8	1.0	6.6
OILTAP® G	1.9	2.2	9.5

Table 20: Humid tropical climate: Annual drying unit demand in kg

4.4 Parallel connection of tap selector planes

Parallel bridges for parallel connection of tap selector planes are available as options for current splitting on the connection contacts of the tap selector or off-circuit tap-changer. Details on this can be found in the technical data of the relevant on-load tap-changer or off-circuit tap-changer.

Parallel bridges are not permitted for applications with enforced current splitting [▶ 35].

For applications without enforced current splitting, parallel bridges are also mandatory if the tapped winding has been wound in two or more branches and each of these branch taps is connected to the connection contacts as a tap.

This measure reliably prevents the following:

- Introduction of circulating currents into the current paths of tap selector and diverter switch
- Commutating arc on movable tap selector contact bridges
- Overvoltage between adjacent connection contacts connected in parallel

Parallel bridges are also mandatory in the event of a tie-in measure [▶ 25] to enable the tie-in resistor to act on all winding parts connected in parallel.

4.5 Installation information

Ensure that the on-load tap-changer and off-circuit tap-changer are installed vertically! On-load tap-changers operating in line with the diverter-switch tap-selector principle and off-circuit tap-changers may deviate by max. 1° from the vertical and on-load tap-changers operating in line with the selector switch principle by max. 1.5° from the vertical.

A deviation due to mechanical loading from connecting leads to the tapped winding is not permitted. The connecting leads must be connected to the tap selector without any mechanical tension.

5 Transformer test information

This chapter contains some basic information about transformer tests. The detailed descriptions of the technical files provided must be noted for the individual products.

Please contact Maschinenfabrik Reinhausen GmbH (MR) if any aspect of the tests is not clear.

5.1 Transformer ratio test

We recommend carrying out a transformer ratio test before the transformer is dried. The following general information must be noted during the test:

- On-load tap-changer and off-circuit tap-changer may only be actuated via the drive shaft of the upper gear unit. The maximum speed of 250 rpm must not be exceeded.
- Performing too many operations without complete oil filling will damage the on-load tap-changer and off-circuit tap-changer! Do not perform more than 250 tap-change operations before drying.
- Before the first actuation after drying
  - the oil compartment of the on-load tap-changer must be completely filled with oil
  - tap selector, off-circuit tap-changer and ARS must be fully submerged in transformer oil.
- The operating position reached must be viewed through the inspection window. The end positions, which are indicated in the connection diagram supplied with the delivery, must never be overshot.

5.2 Measuring DC resistance

Note the measurement scenarios listed below and the associated maximum measured currents when measuring DC resistance on the transformer.

The measured DC current is normally restricted to 10 % of the rated current of the measured transformer winding in order to prevent the winding from overheating.

The DC resistance measurement is taken in various on-load tap-changer and off-circuit tap-changer operating positions.

If the measured current is not interrupted when changing operating position, it must be limited to 10 A DC with an empty on-load tap-changer oil compartment. If the measured current is interrupted when changing operating position (measured current equals 0 A), a maximum permissible value of 50 A DC applies during the measurement.

On-load tap-changer oil compartment	Without interruption during change in operating position	With interruption during change in operating position
Oil compartment empty	Maximum 10 A DC	Maximum 50 A DC
Oil compartment filled with insulating oil	Maximum 50 A DC	Maximum 50 A DC

Table 21: Maximum permissible measured currents

5.3 Operating the on-load tap-changer during the transformer test

If the on-load tap-changer is operated with an excited transformer, this is only permitted at rated frequency. This applies to no-load operation too.

5.4 Electric high voltage test

During the electric high voltage test on the transformer, additional safety notices must be observed, especially for motor-drive unit preparation and operation. You will find a detailed description in the documentation supplied with the motor-drive unit.

5.5 Dielectric test

The motor-drive unit is put through a dielectric test before delivery and must be separated from the section to be tested during this transformer test to rule out the possibility of increased loading for the components fitted in the motor-drive unit.

6 Applications

In addition to the information already provided, the following must be noted for certain applications:

6.1 Transformers for electric arc furnaces

Overloads of up to 2.5 times the rated transformer load occur during normal operation in on-load tap-changers used in transformers for electric arc furnaces. The following measures must be used to adapt the on-load tap-changers to these operating conditions:

VACUTAP® VR® and VM®:

Refer to the step capacity diagrams for electrical arc furnace operation in the technical data for VACUTAP® VR and VM®.

VACUTAP® VV® and OILTAP® MS, M, RM, R and G:

The permissible step capacity is reduced to 80 % of the relevant rated step capacity stated in the technical data of the relevant on-load tap-changer for the rated through-current needed.

OILTAP® V:

OILTAP V200 is not approved for this operating mode. The rated through-current is limited to 200 A for OILTAP V350.

6.2 Applications with variable step voltage

In applications with variable step voltage, the highest possible step voltage is always decisive when selecting the on-load tap-changer. Examples of such applications:

- Variable magnetic flow
- Tapped windings with different numbers of windings
- Load-dependent and position-dependent step voltage with phase shifter transformers
- Operation with line voltage exhibiting unusually large fluctuation

If different pairs of values for step voltage and associated through-current are needed for an on-load tap-changer, the combination of highest step voltage and highest through-current must be within the permissible switching capacity range of the on-load tap-changer type in question, even if this step voltage and through-current do not occur at the same time.

Example:

Operating a transformer with constant power in a large range of fluctuating line voltage. Then the highest step voltage occurs at the highest line voltage together with a low through-current corresponding to the transformer power and the largest through-current occurs together with the lowest step voltage at the lowest line voltage. The on-load tap-changer must then be designed as if the highest step voltage would occur with the highest through-current.

This is because the transition resistor has to be adapted to both the step voltage and through-current. In general for this adaptation: High step voltages require high transition resistor values, whereas high through-currents require low transition resistor values. The problem of transition resistor adaptation can therefore only be solved if there is a resistor value which is suitable for the highest step voltage and at the same time the highest through-current. Otherwise, in the above example, the transition resistor value would have to be constantly adapted to the different line voltages.

The resistor value is appropriate when the pair of values for highest step voltage and highest through-current are within the permissible switching capacity range. If this pair of values is just outside the permissible switching capacity range, Maschinenfabrik Reinhausen GmbH (MR) must check on a case-by-case basis whether there is a way of adapting the transition resistor. If the permissible switching capacity range is vastly exceeded, a tap-changer type with a higher switching capacity must be used.

6.3 Hermetically sealed transformers

If transformers are hermetically sealed, the on-load tap-changer also has hermetic sealing.

Only VACUTAP® on-load tap-changers are approved for such applications.

Depending on the application, no free gases or only very small quantities of free gases, which are fully dissolved in the oil, are produced during normal network operation. Automatic venting is not therefore needed. Since the production of gas is mainly determined by the levels of ambient gases in the oil, on-load tap-changers for hermetic applications must be filled under a vacuum with degased oil.

The following protective concept applies to hermetic applications for VACUTAP® on-load tap-changers:

- There must be a pressure relief device (e.g. MPreC®) on the on-load tap-changer cover. In the event of a fault, it is essential that this trips the transformer's circuit breaker.
- Instead of the RS2001, a Buchholz relay with two floaters (e.g. MSafe®) must be used. The first (top) floater in the Buchholz relay triggers the "Gas warning" message. The second (bottom) floater in the Buchholz relay is linked in terms of function to the swell flap and can also be used to trip the transformer's circuit breaker.

In terms of using alternative insulating liquids for hermetic applications, the same usage conditions and restrictions apply as for free-breathing installations. Natural esters may only be used in combination with hermetically sealed systems.

On request, MR on-load tap-changers can also be used in hermetically sealed transformers with gas blankets. The maximum gas blanket thickness below the transformer cover must be stated in the original query.

6.4 Operation in environments at risk of explosion

The following MR products are certified for operation in areas at risk of explosion:

Product	1	2	3	4	5	6	7	8
VACUTAP® VM-Ex VACUTAP® VR I II III-Ex VACUTAP® VR I HD-Ex VACUTAP® VV-Ex	Ex	II	3G	Ex	nAC	IIC	T3	Gc
Protective relay RS 2001-Ex (GK3)	Ex	II	3G	Ex	nAC	IIC	T4	Gc
Protective relay RS 2001-Ex (GK2)	Ex	II	2G	Ex	ia	IIC	T4	Gb
TAPMOTION® ED 100 S-Ex (200°C)	Ex	II	2G	Ex	px	IIC	T3	Gb
TAPMOTION® ED 100 S-Ex (130°C)	Ex	II	2G	Ex	px	IIC	T4	Gb
Drive shaft Ex (not electrical)	Ex	II	2G	Ex	-	IIC	T4	-

Number	Meaning
1	Sign for explosion protection
2	Equipment group
3	Equipment category
4	Explosion-proof equipment
5	Ignition-protection type
6	Explosion group
7	Temperature class
8	Equipment protection level

Note that the EX models of the on-load tap-changers and protective relay are only approved when using mineral oil in accordance with IEC 60296 or synthetic ester liquids in accordance with IEC 61099.

The on-load tap-changer overload is limited to 1.5 times the rated current.

For more detailed information, consult the product-specific technical files or go to the REINHAUSEN corporate website: www.reinhausen.com.

6.5 Special applications

The information provided in the order details and associated completion guide must be observed for on-load tap-changers for other special applications (e.g. high voltage DC transmission, generator operation, phase shifter, traction transformers, restrictors, applications with split star point, etc.). Please contact Maschinenfabrik Reinhausen GmbH (MR) if you have any queries.

7 Drives for on-load tap-changers and off-circuit tap-changers

7.1 TAPMOTION® ED motor-drive unit

This chapter contains a function description, an explanation of the type code and the most important technical data for the TAPMOTION® ED motor-drive unit.

The associated dimensional drawings are attached, see [▶ 76].

For more detailed information and information for special variants, consult the product-specific technical files or go to the REINHAUSEN corporate website: www.reinhausen.com.

7.1.1 Function description

The motor-drive unit works by adjusting the operating position of on-load tap-changers and off-circuit tap-changers in regulating transformers to the individual operating requirements.

The tap-change operation is activated by starting the motor-drive unit (a single control impulse triggered, for example, by a regulator of the TAPCON®-series). This operation is always completed regardless of any other control pulses emitted during the tap-change operation. In the standard design, the next tap-change operation can only proceed once all control devices have reached their rest positions.

7.1.2 Type designation

The various basic designs of the TAPMOTION® ED are clearly identified by explicit product definitions.

Type designation	Description	Variants
ED 100-ST	Product designation	Electric Drive
ED **100**-ST	Transmission gear design	100 or 200 (depending on the torque required)
ED 100-**S**T	Protective housing design	S = small protective housing L = large protective housing
ED 100-S**T**	Special applications	… = none C = Plunger coil design T = TAPCON® or TAPGUARD®

Type designation	Description	Variants
ED 100-S-**ISM**	Special application	ISM = "Integrated Smart Module" for recording, aggregating and interpreting data on the transformer

Table 22: Type designation

7.1.3 Technical data for TAPMOTION® ED

The technical data is relevant to the standard model and may vary depending on the model delivered. Subject to change without prior notice.

Motor-drive unit	**ED 100-S/L**	**ED 200-S/L**	
Motor power	0.75 kW	2.0 kW	2.2 kW
Motor circuit voltage supply	3 AC/N 230/400 V		
Current	approx. 1.9 A	approx. 5.2 A	approx. 6.2 A
Frequency	50 Hz		
Synchronous speed	1,500 rpm		
Rotations of the drive shaft per tap-change operation	16.5		
Duration of the tap-change operation	approx. 5.4 s		
Rated torque on the drive shaft	45 Nm	90 Nm	125 Nm
Rotations of the hand crank per tap-change operation	33		54
Maximum number of operating positions	35		
Control and heating circuit voltage supply	AC 230 V		
Power input of the control circuit (control / operation)	100 VA/25 VA		
Heating power	50 W for ED 100/200 S 60 W for ED 100/200 L		
Temperature range (ambient temperature)	- 25 °C to + 50 °C		
Protection from foreign objects and water	IP 66 in accordance with DIN EN 60529		
Test voltage to ground	2 kV/60 s		
Weight	maximum 130 kg		

Table 23: Technical data for TAPMOTION® ED

7.2 TAPMOTION® DD manual drive

This chapter contains a function description and the most important technical data for the TAPMOTION® DD manual drive.

For more detailed information and information for special variants, consult the product-specific technical files or go to the REINHAUSEN corporate website: www.reinhausen.com.

7.2.1 Function description

The manual drive works by adjusting the operating position of off-circuit tap-changers in regulating transformers to the individual operating requirements.

The tap-change operation is initiated by actuating the manual drive. Once a tap-change operation is complete, the manual drive is forcibly locked. Another tap-change operation is only possible once the manual drive is manually unlocked.

7.2.2 Technical data for TAPMOTION® DD

Manual drive	
Protective housing	for outdoor design, protection IP 55
Gearing	Transmission gear for hand crank operation, ratio 2:1 and auxiliary gear for the tap position indicator and blocking of drive mechanism
Maximum transferable torque	approx. 90 Nm on the output shaft with approx. 200 N applied to the hand crank handle
Number of operating positions	Maximum 17
Rotations of the hand crank per tap-change operation	8
Tap position indicator	Position-indication disk behind inspection window
Tap-change indicator	Display behind inspection window
Safety devices	**Mechanical locking** Padlock, release needed for every tap-change operation (enforced latch) **Electrical locking** Cam switch, switched over when unlocked by the operating lever Switching capacity: 24...250 V = 100 W AC/DC **Electro-mechanical lock (optional)** Locking magnet; the locking magnet (Y1) must be unlocked before the tap-change operation by applying the corresponding voltage (depending on version 110...125 V DC, 220 V DC, 95...140 V AC or 230 V AC).
Housing dimensions	420 x 434 x 199 mm (W x H x D)
Weight	about. 25 kg

Manual drive	
Temperature range	- 45 °C…+ 70 °C

Table 24: Technical data for TAPMOTION® DD

8 Drive shaft

This chapter contains a function description and information about the structure, models and lengths in which the drive shaft is supplied. A dimensional drawing of the associated bevel gear is attached, see [▶ 78].

For more detailed information, consult the product-specific technical files or go to the REINHAUSEN corporate website: www.reinhausen.com.

8.1 Function description

The drive shaft is the mechanical connection between motor-drive and on-load tap-changer head or off-circuit tap-changer head. The bevel gear changes the direction from vertical to horizontal. Accordingly, the vertical drive shaft has to be mounted between drive and bevel gear and the horizontal drive shaft between bevel gear and on-load tap-changer or off-circuit tap-changer.

8.2 Setup/models of drive shaft

The drive shaft consists of a square tube and is coupled by two coupling brackets and one coupling bolt at both ends to the drive / driven shaft end of the device to be connected.

8.2.1 Drive shaft without cardan shaft, without insulator (= normal model)

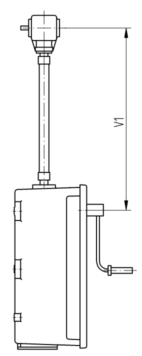


Figure 22: Drive shaft without cardan shaft, without insulator (= normal model)

Configuration	V 1 min [mm]	Intermediate bearing for [mm]
Middle of hand crank – middle of bevel gear (maximum permissible axial offset 2°)	526	V 1 > 2462

8.2.2 Drive shaft without cardan shaft, with insulator (= special model)

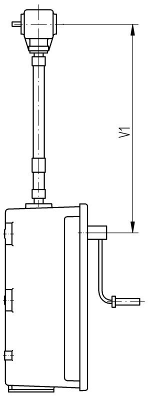


Figure 23: Drive shaft without cardan shaft, with insulator (= special model)

Configuration	V 1 min [mm]	Intermediate bearing for [mm]
Middle of hand crank – middle of bevel gear (maximum permissible axial offset 2°)	697	V 1 > 2462

8.2.3 Drive shaft with cardan shaft, without insulator (= special model)

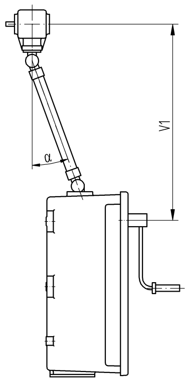


Figure 24: Drive shaft with cardan shaft, without insulator (= special model)

Configuration	V 1 min [mm]	Intermediate bearing for [mm]
Middle of hand crank – middle of bevel gear (maximum permissible axial offset alpha = 20°)	790	V 1 > 2556

8.2.4 Drive shaft with cardan shaft, with insulator (= special model)

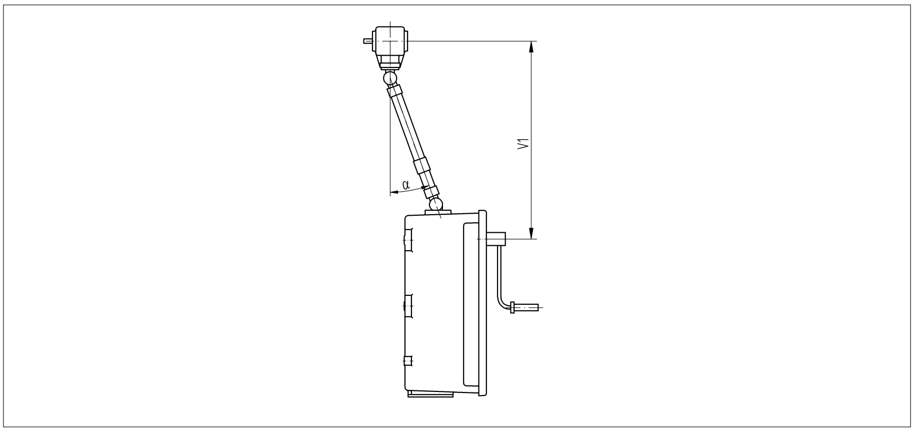


Figure 25: Drive shaft with cardan shaft, with insulator (= special model)

Configuration	V 1 min [mm]	Intermediate bearing for [mm]
Middle of hand crank – middle of bevel gear (maximum permissible axial offset alpha = 20°)	975	V 1 > 2556

8.2.5 Delivery lengths

The square tubes and the vertical protective cover are supplied in overlengths (graded standard lengths). These parts must be cut to the required size before mounting on the transformer. In rare cases the inner tube of the telescopic protective tube has to be cut.

The following unit lengths are available for linking to the motor-drive unit and manual drive: 400 mm, 600 mm, 900 mm, 1,300 mm, 1,700 mm, 2,000 mm. The unit length 2,500 mm may only be used in conjunction with the manual drive and is only available for vertical installation without shaft protection. The maximum total drive shaft length of the drive to the last pole is 15 m.

9 RS protective relay

This chapter contains a function description and the most important technical data for the RS protective relay. Additional information about protective devices can be found in the Pressure loading during operation [▶ 43] chapter.

For more detailed information and information for special variants, consult the product-specific technical files or go to the REINHAUSEN corporate website: www.reinhausen.com.

9.1 Function description

The RS protective relay is used to protect the on-load tap-changer and the transformer when a malfunction occurs in the on-load tap-changer oil compartment. It is tripped when the specified speed of oil flow from the on-load tap-changer head to the oil conservator is exceeded due to a fault. The flowing oil actuates the flap valve which tips over into position OFF. The contact in the dry-reed magnetic switch is thereby actuated, the circuit breakers are tripped and the transformer is de-energized.

Diverter switch operations at rated switching capacity or at permissible overload will not cause the protective relay to trip. The protective relay responds to oil flow, not to gas accumulated in the protective relay. It is not necessary to bleed the protective relay when filling the transformer with oil. Gas accumulation in the protective relay is normal.

The protective relay is part of an oil-insulated on-load tap-changer and its properties conform to IEC publication 60214-1 in the applicably valid version. Therefore, it is part of the scope of our delivery.

9.2 Technical data

General technical data

Housing	Outdoor model
Protection	IP 54
Relay actuation	Flap valve with aperture
Weight	About 3.5 kg
Oil flow speed of available types when tripping (oil temperature 20 °C):	0.65 m/s 1.20 m/s 3.00 m/s 4.80 m/s

Table 25: General technical data

Tripping switch

The protective relay can be supplied with either a normally open (NO) or a normally closed (NC) dry-reed magnetic switch (see dimensional drawing supplied).

Other contact combinations are available as special design .

Electrical data for normally open (NO) or normally closed (NC) dry-reed magnetic switch

AC switching capacity DC switching capacity	1.2 VA…400 VA 1.2 W…250 W
Maximum admissible voltage AC/DC Minimum admissible voltage AC/DC	250 V 24 V
Maximum switched current AC/DC Minimum switched current AC/DC	2 A 4.8 mA at 250 V
Power frequency withstand voltage test	Between all voltage-carrying connections and the grounded parts: at least 2500 V, 50 Hz, test duration 1 minute Between open contacts: at least 2000 V, 50 Hz, test duration 1 minute

Table 26: Electrical data for normally open (NO) or normally closed (NC) dry-reed magnetic switch

10 OF 100 oil filter unit

This chapter contains a function description, usage criteria and the most important technical data for the OF 100 oil filter unit.

For more detailed information and information for special variants, consult the product-specific technical files or go to the REINHAUSEN corporate website: www.reinhausen.com.

10.1 Function description

During each diverter switch operation, the OF 100 oil filter unit automatically handles cleaning and, together with the combined filter cartridge, also drying of the on-load tap-changer's insulating oil.

The flange connections for oil feed are located on the bottom cover of the pump unit, and the flange connections for oil return are located on the top cover. The pump draws in the insulating oil via the suction pipe of the on-load tap-changer and via the pipe for the forward flow. The insulating oil enters the bottom of the tank of the pump unit and is pressed through the filter cartridge by the pump.

The cleaned insulating oil, or in the case of the combined filter cartridge the cleaned and dried insulating oil, leaves the pump unit via the return pipe and flows back through the return pipe connection to the on-load tap-changer head.

In the standard version of the OF 100 oil filter unit, the pressure switch which is set at the factory to 3.6 bar is used for remote indication of the working pressure. At a pressure of 3.6 bar, the pressure switch closes a signaling contact and indicates that the limit value has been reached.

When the standard oil filter unit starts up at a low oil temperature, the pressure switch may trip because the oil viscosity increases as the temperature falls and the operating pressure therefore rises. This message can be ignored when the oil temperature is under 20 °C.

Special model with temperature switch

To prevent the pressure switch from issuing erroneous signals at temperatures below 20 °C, the pressure switch signal can be suppressed below 20 °C at the request of the customer by an extra built-in temperature switch.

Model for cold weather operation

The model for cold weather operation is recommended for regions where the temperatures may fall below 5 °C in the OF 100 oil filter unit or in the pipes. A thermostat which switches the oil filter unit to permanent operation when temperatures fall below 0 °C is used for this purpose. The oil filter unit remains in permanent operation until the oil temperature exceeds + 5 °C.

10.2 Criteria for operation

To ensure perfect oil filter unit functions, one pump unit with filter cartridge must be installed per switching column.

Use of an oil filter unit with **paper filter cartridge** is recommended for the operation of on-load tap-changers in transformers with an annual number of switching operations of more than 15,000. The maintenance intervals can therefore be extended.

Using an oil filter unit with **combined filter cartridge** also reduces the oil's water content.

Use of the OF 100 oil filter unit with combined filter cartridge is mandatory for the following applications in order to observe the dielectric properties required of the insulating oil:

OILTAP® on-load tap-changer Type ...	U_m [kV] highest voltage for OLTC equipment	U_b [kV] highest operating voltage (phase-phase)
M I, RM I, R I, G I M III ...K	300	$245 \leq U_b < 260$
RM I, R I, G I	362	$260 \leq U_b < 300$
RM I, R I, G I	on request	≥ 300
M III ...D	123	$79 < U_b \leq 123$
V III ...D	76	$55 < U_b \leq 79$

Table 27: Criteria for use of oil filter unit with combined filter cartridge

If the oil filter unit is used in the oil cooling system, the use of combined filter cartridges is also mandatory.

If necessary, on-load tap-changers already in operation can be retrofitted with an oil filter unit following consultation with Maschinenfabrik Reinhausen GmbH (MR).

10.3 Technical data

Pump motor (standard)	Power Voltage Rated current Frequency Synchronous speed	1.1 kW 3 AC 230/400 V (other voltages on request) 4.10/2.35 A 50 Hz or 60 Hz 3,000 rpm (50 Hz), 3,600 rpm (60 Hz)
Pump (centrifugal pump)	Capacity	approx. 65 l/min (35 l/min), at counter pressure of 0.5 bar (3.6 bar)
Filter cartridges (alternative)	Paper filter	for cleaning the insulating oil, filter fineness around 9 µm
	Combined filter	for cleaning and drying the insulating oil, filter fineness around 9 µm
	Water absorption capacity around 400 g	
Tank	Steel cylinder with lid and base, outdoor model	
	Dimensions (WxHxD)	410x925x406 mm
	Exterior paint	RAL 7033
	Test pressure	6 bar
	Flange connection for feed and return	
	Manometer (mounted on tank)	
	Pressure switch (mounted on tank)	▪ Setting range 0...6 bar, preset to 3.6 bar ▪ Switching capacity AC 250 V, I_{max} = 3 A ▪ P_{max} = 500 VA/250 W
	Weight of pump unit (dry)	around 75 kg
	Oil capacity	around 35 l
Controller in motor-drive unit of tap changer	Installation of operating controls in swivel frame front of motor-drive unit (IP 66)	
	Voltage	AC 230 V
Controller in separate control cabinet (special model)	Installation of components in separate control cabinet (IP 55)	
	Dimensions (WxHxD)	400x600x210 mm
	Paint	RAL 7033
	Weight	around 10.5 kg
	Voltage	AC 230 V
	Heating	▪ Voltage: AC 230 V ▪ Power: 15 W

11 On-load tap-changer selection

11.1 Selection principle

The choice of on-load tap-changer is ideal from a technical and cost standpoint if it meets the requirements made of the on-load tap-changer due to the transformer's operating and test conditions. Safety margins do not generally have to be added to individual on-load tap-changer data.

When selecting the on-load tap-changer, you need the following important data about the transformer winding to which the on-load tap-changer is to be connected.

A) Transformer winding data	
1	Rated power P_N
2	Connection (Y, delta or single-phase connection)
3	Rated voltage, regulating range: U_N (1 ± x %)
4	Number of positions, basic connection for tapped winding
5	Rated insulation level
6	Voltage stress of tapped winding when testing with lightning impulse voltage and induced AC voltage

This produces the phase sizes for the on-load tap-changer.

B) Basic on-load tap-changer data	**Resulting from the transformer winding data (table above):**
Maximum rated through current I_u	1, 2, and 3
Rated step voltage U_i	3 and 4
Rated step capacity $P_{StN} = I_u \cdot U_i$	Calculated value

The suitable on-load tap-changer is identified by the following features:

C) Identification of on-load tap-changer	
Step 1	
	On-load tap-changer type
	Number of phases
	Maximum rated through current I_{um}
Step 2	
	Highest voltage for equipment U_m of on-load tap-changer
	Tap selector size
	Basic connection diagram

We would recommend consulting the product-specific technical data for the correct selection.

If necessary, the following key on-load tap-changer data must also be checked:

- Breaking capacity of on-load tap-changer
- Permissible loading with short-time current
- Contact life of diverter switch

11.2 Example 1

Find the right on-load tap-changer for a three-phrase current power transformer with the following data:

A) Transformer winding data		
1	Rated power	P_N = 80 MVA
2	Tap-change operation	Y connection
3	Rated voltage, regulating range of high voltage winding	U_N = 110 (1 ± 11 %) kV
4	Number of positions, basic connection for tapped winding	± 9 taps, reversing change-over selector connection
5	Rated insulation level of high voltage winding	Rated short-duration power frequency withstand voltage (50 Hz, 1 min.) 230 kV Rated lightning impulse withstand voltage (1.2/50 µs): 550 kV
6	Voltage stress of tapped winding when testing with lightning impulse voltage and induced AC voltage	Lengthwise regulating range for one phase: 250 kV (1.2/50 µs), 16 kV (50 Hz, 1 min.) between the taps of different phases: 220 kV (1.2/50 µs), 24 kV (50 Hz, 1 min.)

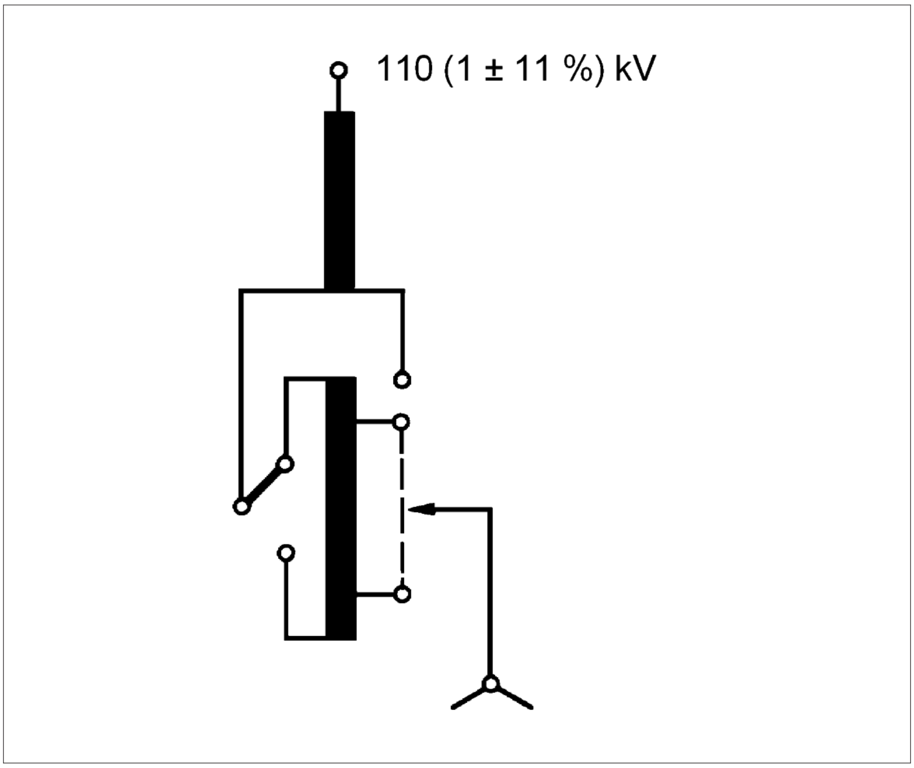


Figure 26: On-load tap-changer selection for example 1

B) Basic on-load tap-changer data	Resulting from the transformer winding data (table above):
Rated through current	$I_u = 80 \cdot 10^6 \text{ VA} / (110\,(1 - 11\,\%) \cdot 10^3 \text{ V} \cdot \sqrt{3}) = 472 \text{ A}$
Rated step voltage	$U_i = 110 \cdot 10^3 \text{ V} \cdot 11\,\% / (9 \cdot \sqrt{3}) = 777 \text{ V}$
Rated step capacity	$P_{StN} = 472 \text{ A} \cdot 777 \cdot 10^{-3} \text{ kV} = 367 \text{ kVA}$

C) Identification of on-load tap-changer		
Step 1		Selection of on-load tap-changer model in accordance with technical data for VACUTAP® VM®
	On-load tap-changer type	VACUTAP® VM®
	Number of phases	3
	Maximum rated through current I_{um}	500 A
Step 2		Calculation of highest voltage for equipment U_m, of tap selector size and basic connection diagram
	Highest voltage for equipment U_m of on-load tap-changer	123 kV
	Tap selector size	B
	Basic connection diagram	10 19 1 W

D) Type designation		VACUTAP® VM III 500 Y – 123 / B – 10 19 1 W	
VM III 500 Y	Type, number of phases, I_u	Rated power	80 MVA
		Rated through current	472 A
		Tap-change operation	Y
123 / B	U_m, tap selector size	Rated voltage, regulating range	110 (1 ± 11 %) kV
		Insulation to ground	550 kV (1.2/50 µs) 230 kV (50 Hz, 1 min.)
		Insulation for lengthwise regulating range	250 kV (1.2/50 µs) 16 kV (50 Hz, 1 min.)
10 19 1 W	Basic connection diagram	Number of positions	± 9 taps
		Change-over selector	Reversing change-over selector

Table 28: On-load tap-changer selection for example 1

11.3 Example 2

Find the right on-load tap-changer for a three-phrase current auto transformer with the following data:

A) Transformer winding data		
1	Rated power	P_N = 400 MVA
2	Tap-change operation	Y connection
3	Rated voltage, regulating range of high voltage winding	U_N = 220 (1 ± 18 %) kV / 110 kV
4	Number of positions, basic connection for tapped winding	± 11 taps, reversing change-over selector connection
5	Rated insulation level of parallel winding	Rated short-duration power frequency withstand voltage (50 Hz, 1 min.): 230 kV Rated lightning impulse withstand voltage (1.2/50 µs): 550 kV
6	Voltage stress of tapped winding	Lengthwise regulating range: 480 kV (1.2/50 µs), 49 kV (50 Hz, 1 min.)

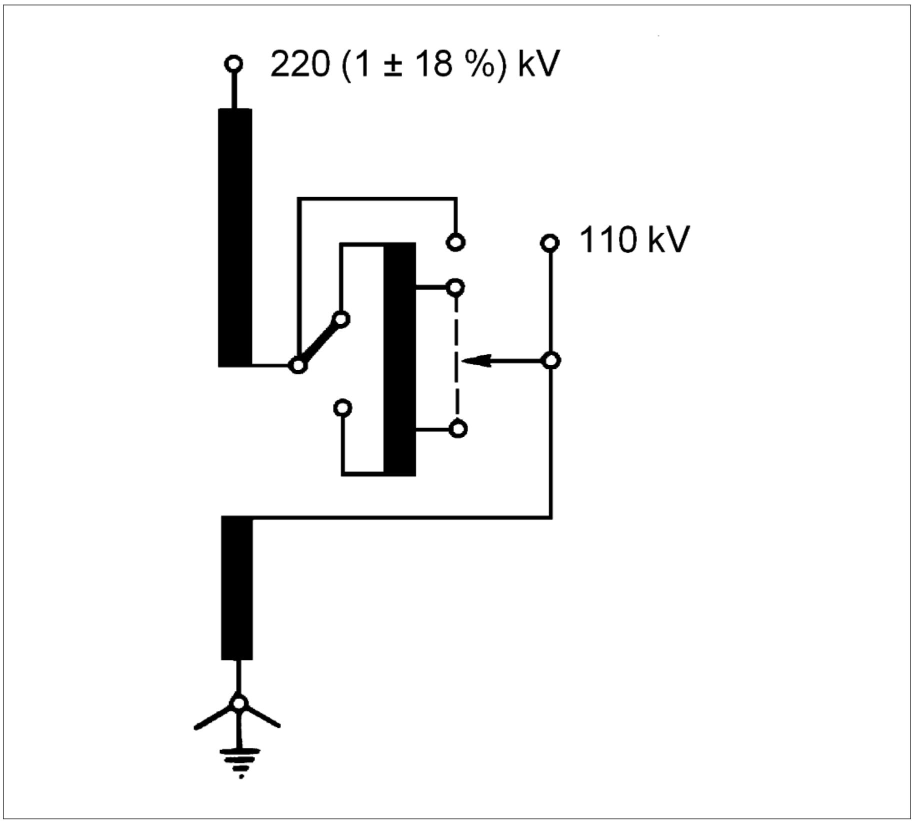


Figure 27: Selection of on-load tap-changer for example 2

B) Basic on-load tap-changer data	Resulting from the transformer winding data (table above):
Rated through current	$I_u = 400 \cdot 10^6\ \text{VA} / (220\ (1 - 18\ \%) \cdot 10^3\ \text{V} \cdot \sqrt{3}) = 1{,}280\ \text{A}$
Rated step voltage	$U_i = 220 \cdot 10^3\ \text{V} \cdot 18\ \% / (11 \cdot \sqrt{3}) = 2{,}078\ \text{V}$
Rated step capacity	$P_{StN} = 1{,}280\ \text{A} \cdot 2{,}078 \cdot 10^{-3}\ \text{kV} = 2{,}660\ \text{kVA}$

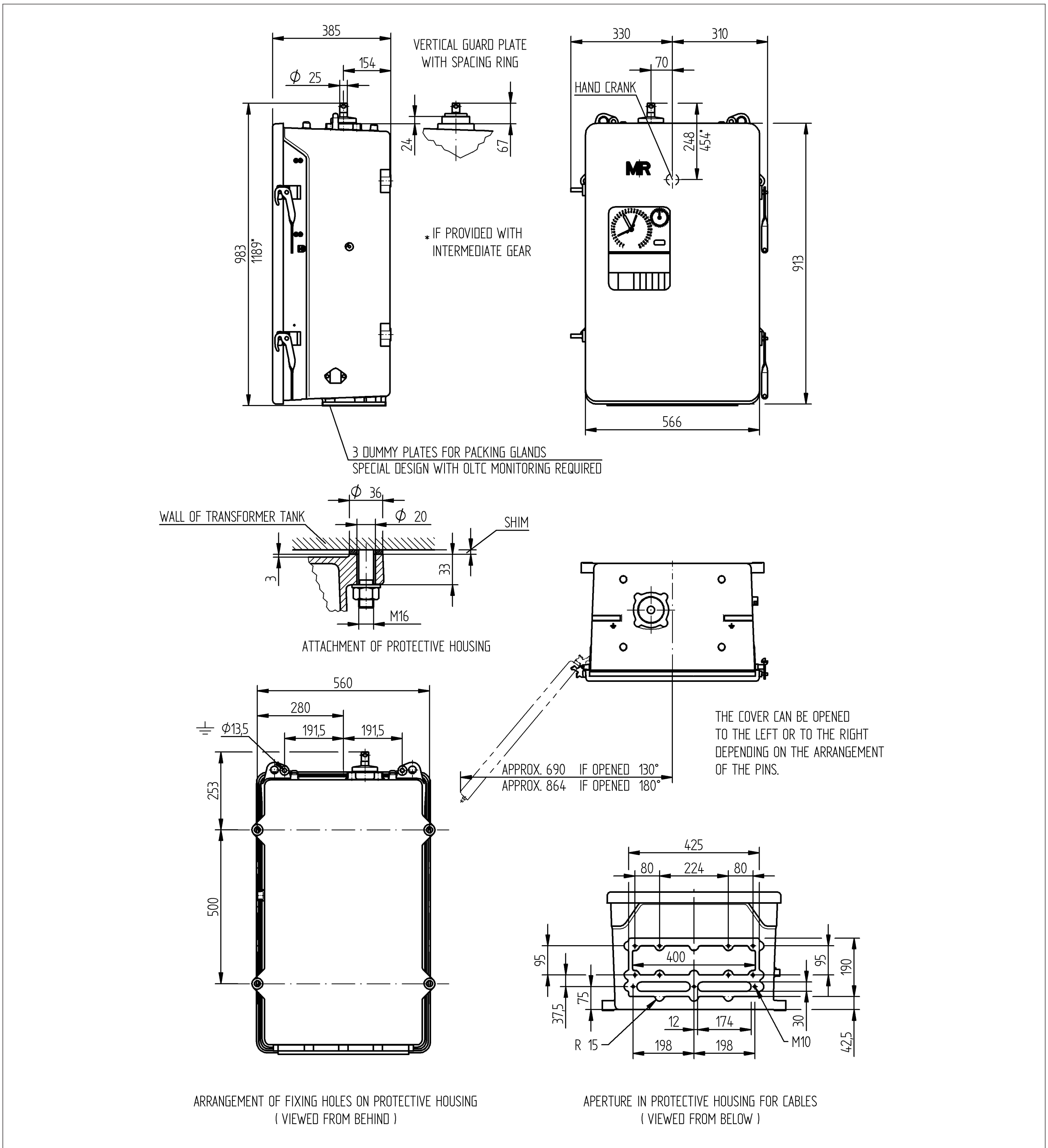
C) Identification of on-load tap-changer		
Step 1		Selection of on-load tap-changer model in accordance with technical data of VACUTAP® VR®
	On-load tap-changer type	VACUTAP® VRF
	Number of phases	3 x 1 phase
	Maximum rated through current I_{um}	1,300 A
Step 2		Calculation of highest voltage for equipment U_m, of tap selector size and basic connection diagram
	Highest voltage for equipment U_m of on-load tap-changer	123 kV
	Tap selector size	D
	Basic connection diagram	12 23 1 W

D) Type designation		3 x VACUTAP® VRF I 1301 – 123/D – 12 23 1 W	
3 x VRF I 1301	Type, number of phases, I_u	Rated power	400 MVA
		Rated through current	1,280 A
		Tap-change operation	Auto transformer
123 / D	U_m, tap selector size	Rated voltage, regulating range	220 (1 ± 18 %) kV
		Insulation to ground	550 kV (1.2/50 μs) 230 kV (50 Hz, 1 min.)
		Insulation for lengthwise regulating range	480 kV (1.2/50 μs) 49 kV (50 Hz, 1 min.)
12 23 1 W	Basic connection diagram	Number of positions	± 11 taps
		Change-over selector	Reversing change-over selector

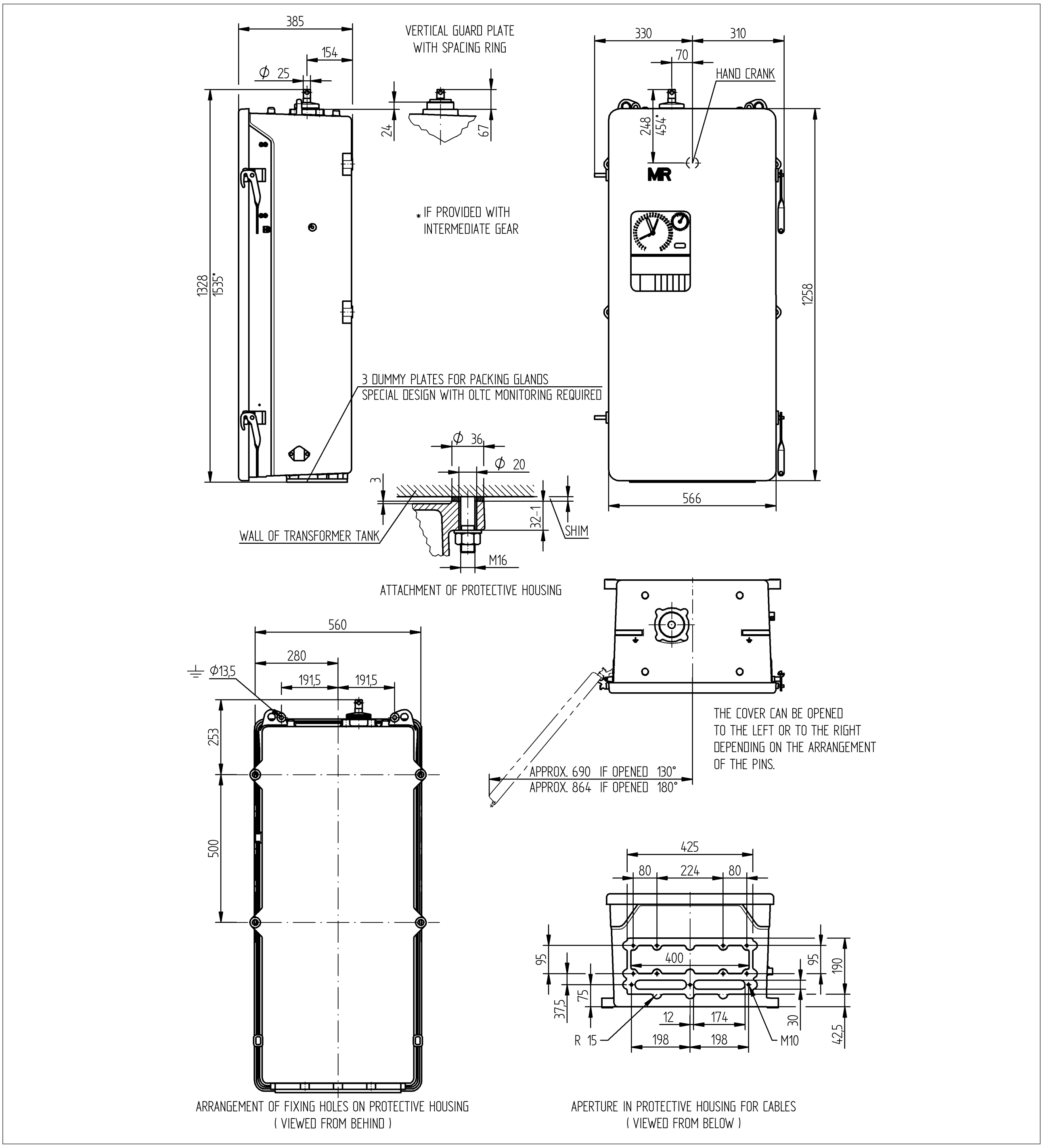
Table 29: Selection of on-load tap-changer for example 2

12 Appendix

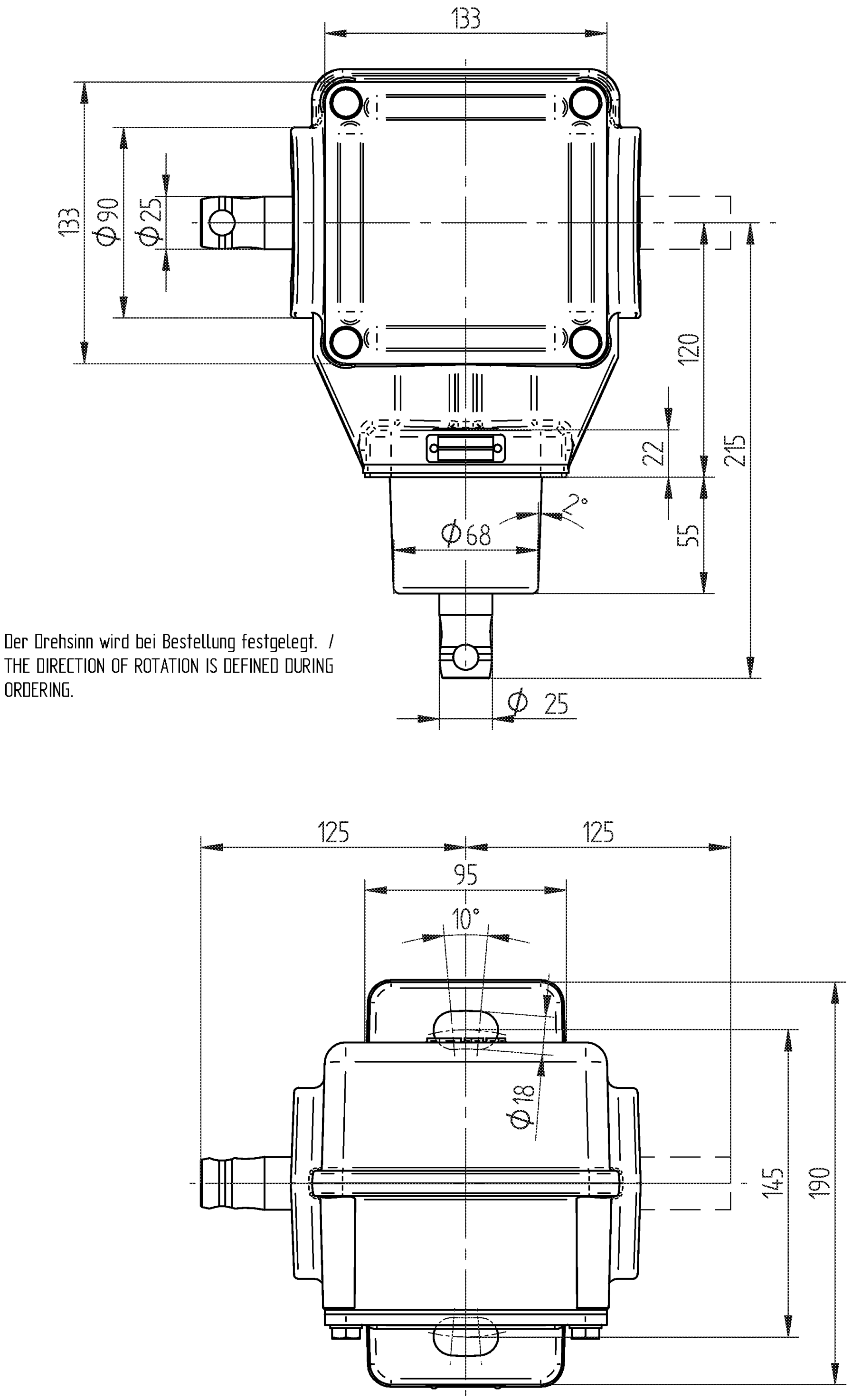
12.1 TAPMOTION® ED-S, protective housing (898801)



12.2 TAPMOTION® ED-L, protective housing (898802)



12.3 Bevel gear - dimensional drawing (892916)



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061/03 EN ▪ 08/13 ▪ F0017402