ECOTAP® VPD®

THE COMPACT CLASS FOR DISTRIBUTION TRANSFORMERS.

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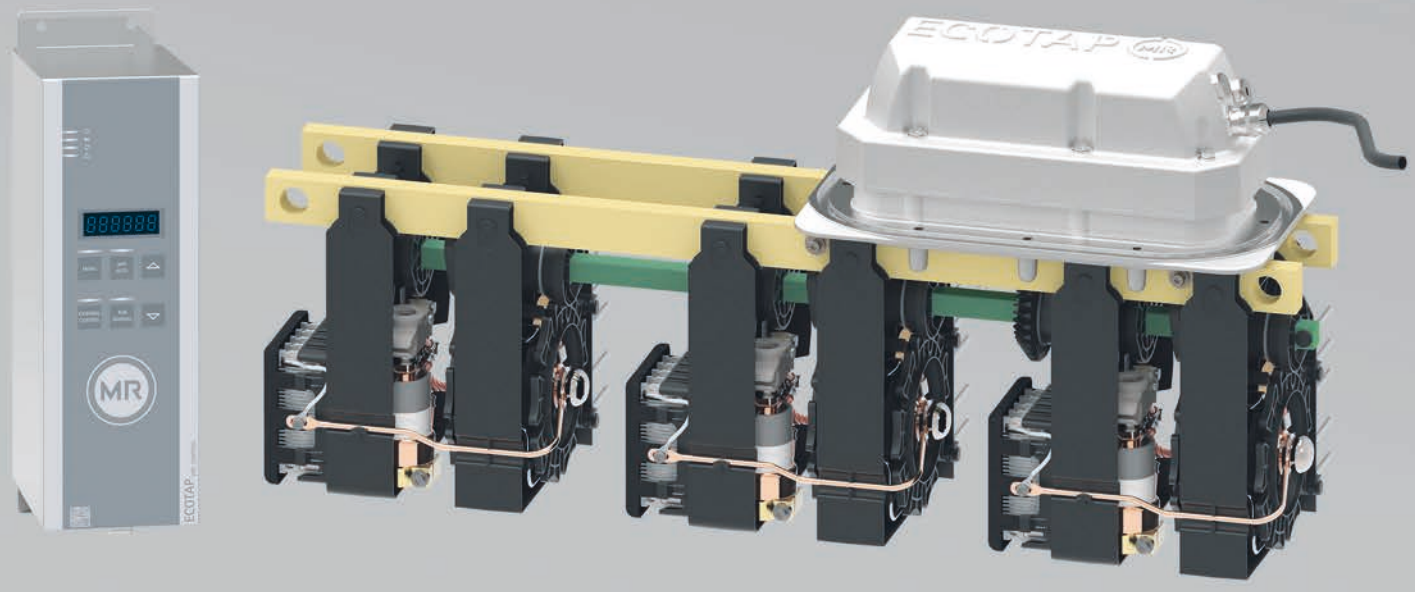


ON-LOAD TAP-CHANGERS WITH VACUUM TECHNOLOGY – NOW ALSO AVAILABLE FOR DISTRIBUTION TRANSFORMERS.

Compact, reliable, and maintenance free: With the superior vacuum technology for on-load tap-changers from Maschinenfabrik Reinhausen (MR), distribution transformers can now be regulated. They maintain a constant voltage in public, industrial, and private distribution grids by compensating for fluctuations in the medium and, if necessary, high-voltage levels and responding dynamically to changes in the feed-in and demand at the low-voltage level.

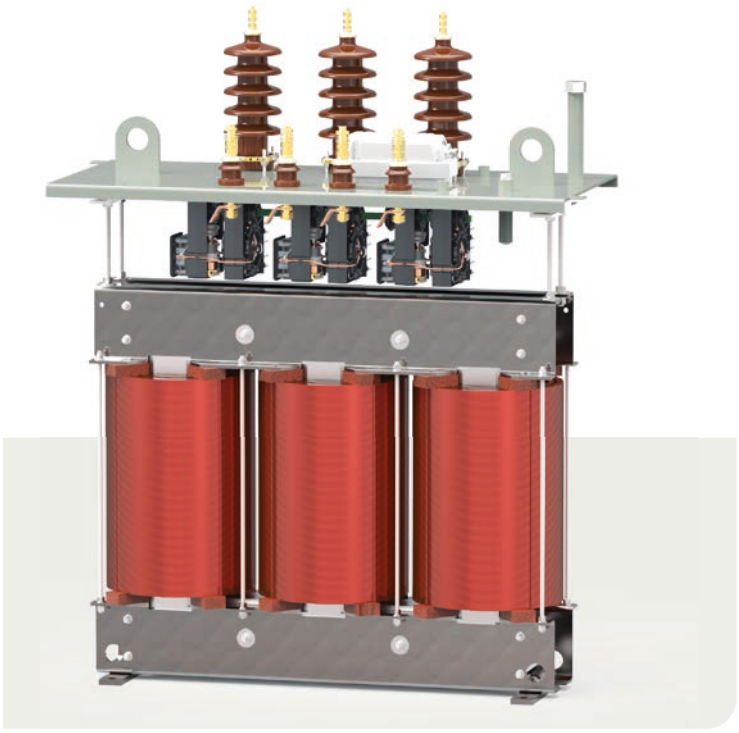
Multi-talented: voltage regulation distribution transformers

- stabilize grids with limited short-circuit power
- allow renewable energy to be integrated into grids without expensive grid reinforcement
- increase the operating efficiency of electricity grids
- stabilize industrial processes
- help to reduce energy costs in the operating environment
- simplify the cost-effective connection of wind farms and solar parks in compliance with the grid code

Tried and tested concept from the transmission grid

Voltage regulation transformers, which allow the transmission ratio and therefore voltages to be dynamically modified, are standard in high-voltage grids and supergrids the world over. Most of the on-load tap-changers needed for this are supplied by MR. However, in the past transformers connected to medium voltage generally only had a de-energized tap-changer which allows a voltage adjustment only after the transformer has been switched off. This situation, which has prevailed for decades, is beginning to change with technical advances in voltage regulation technology and recent changes in grids.

The benefits resulting from the dynamic adjustment of voltage in the distribution grid and therefore in medium and low voltage are being increasingly seen in grid planning and operation. As is already the case in higher voltage levels, here the vacuum on-load tap-changer is also the product of choice for adding voltage regulation during operation to the previously static transformers in the distribution grid.

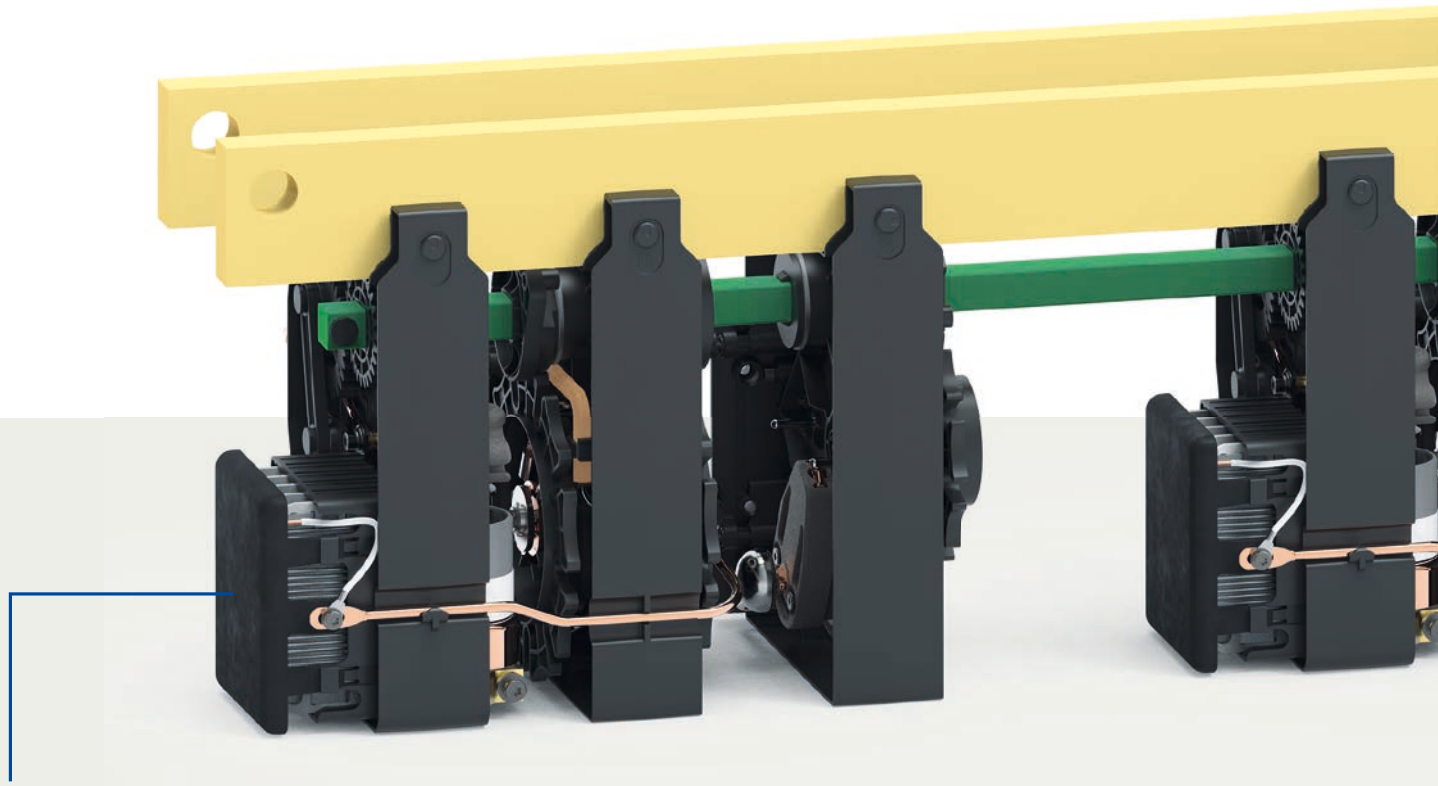


ECOTAP® VPD® ON-LOAD TAP-CHANGER.

Sometimes big things can be surprisingly compact.

ECOTAP® VPD® combines the know-how that MR has accumulated over the decades in vacuum on-load tap-changers of the high-speed resistor-type technology with the experience in voltage regulation distribution transformers gained around the globe since 2012 through working with transformer manufacturers and operators. ECOTAP® VPD® allows all manufacturers of distribution transformers to add voltage regulation transformers to their product range: With superior MR vacuum technology and at a price which makes the transformer/on-load tap-changer system very attractive to a lot of operators.

- The compact dimensions permit installation in virtually any power rating class of distribution transformers without any major changes to the footprint
- The proven electro-mechanical operating principle of MR's vacuum technology ensures stable and reliable operation for decades without the need to service the primary equipment
- Use of the high-speed resistor-type tap-changer principle, with which manufacturers and operators have been familiar for decades, ensures that design, production, testing, and operation can be carried out on the basis of previous experience and that comprehensive training is not needed

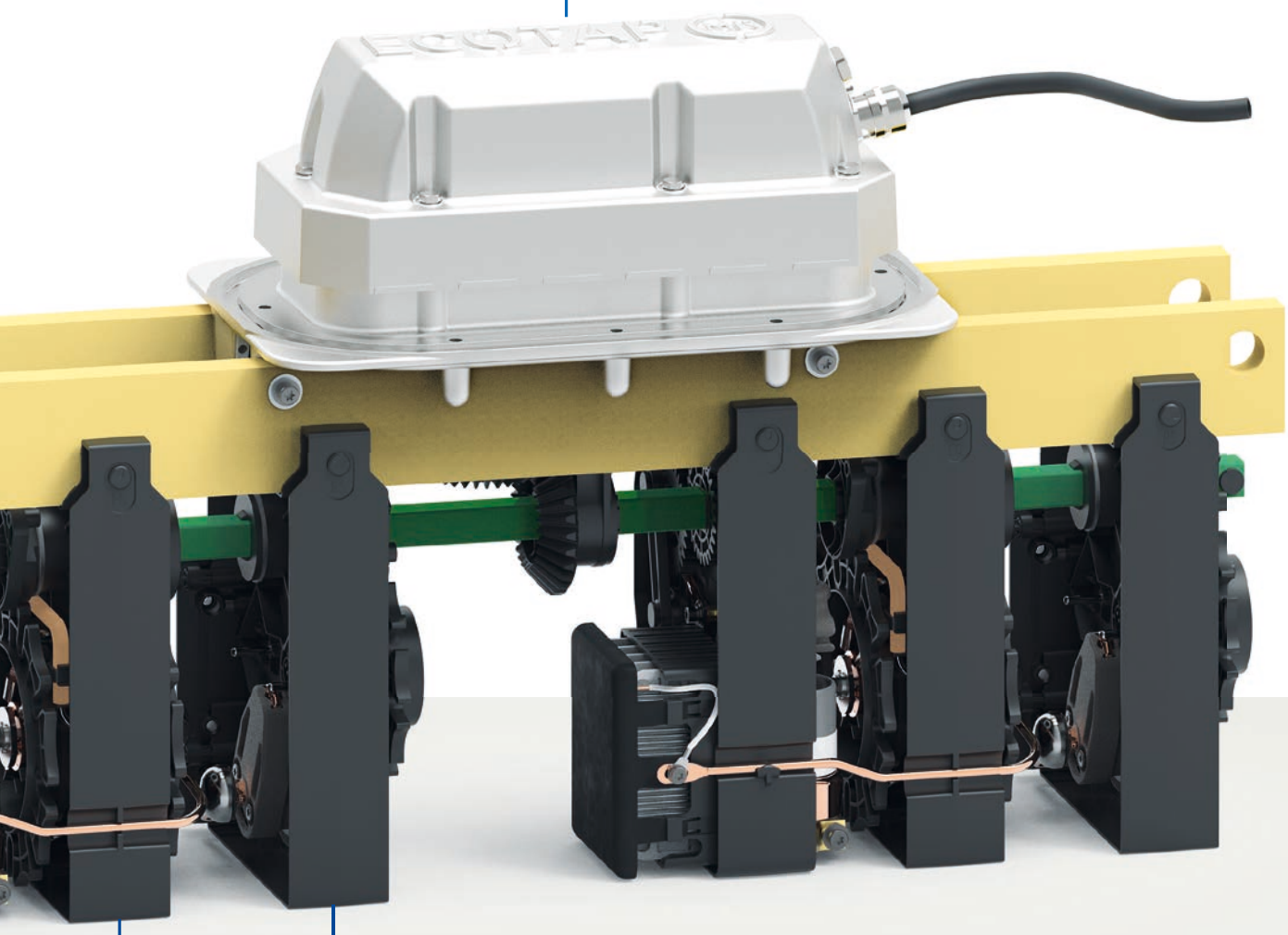


Switching unit

- Vacuum interrupter prevent the transformer oil from being contaminated and ensure that the primary equipment does not need service
- A step voltage of up to 825 V, highest voltage for equipment of up to 40.5 kV, and switchable currents of up to 30 A / 100 A enable a wide range of use in transformers of up to 8 MVA (depending on the transformer's high voltage)
- The high-speed resistor-type tap-changer principle with regulation on the high-voltage side prevents noticeable contributions to transformer losses and ensures compliance with the EU Ecodesign Directive

Direct drive

- A maximum of 20 tap-change operations per minute enable quick responses to changing grid situations
- Comprehensive safety functions and an electrical energy accumulator ensure that once tap-change operations are started they are reliably completed even if all power is lost
- Can be used outdoors thanks to IP54 degree of protection



Selector moduls

- The robust mechanics permit 500,000 tap-change operations without maintenance (more than the usual life of a corresponding distribution transformer)
- 9 or 17 operating positions ensure a large regulation range together with fine tap-change steps
- Since it can be used in selected synthetic and natural esters, operation in applications with stringent environmental compatibility and thermal demand requirements is also ensured

ECOTAP® VPD® – CONTROL AND VOLTAGE REGULATION.

Compact, robust, user friendly, and extendable.

Compact and robust

- Just 10 cm wide and 35 cm tall
- Using an adapter, can be installed on the busbar to the width of a fuse panel to save space
- Wide temperature range of -25°C to +70°C
- High electrical interference level of up to 4 kV
- Degree of protection IP30, with optional housing IP54
- Designed for a life of 20 years

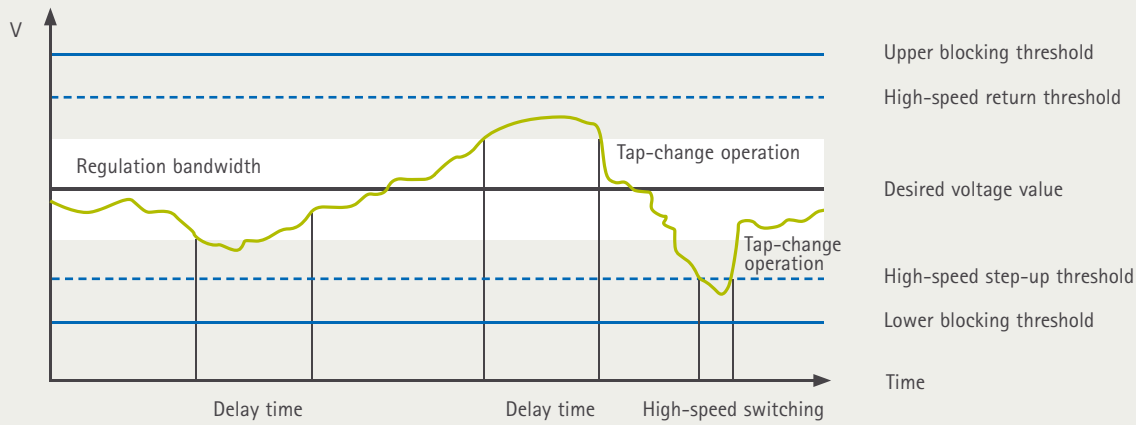
User friendly

- Auto mode with single-phase voltage regulation algorithm
- Manual mode with raise-lower operation
- Complete parameterization on the controller possible, no laptop needed
- Comprehensive indication of status in the display

Expandable by the additional module CONTROL PRO

- Remote communication in accordance with IEC 60870-4-104, IEC 61850, DNP3, MODBUS TCP
- Advanced voltage regulation algorithms, such as power-based voltage characteristics curves
- Parallel operation regulation
- Three-phase voltage and current measurement
- Storage of Power Quality measurements

Reliable regulation algorithm based on the busbar voltage measured in one phase



OPTIMIZED FOR MANUFACTURERS OF DISTRIBUTION TRANSFORMERS AND OPERATORS.

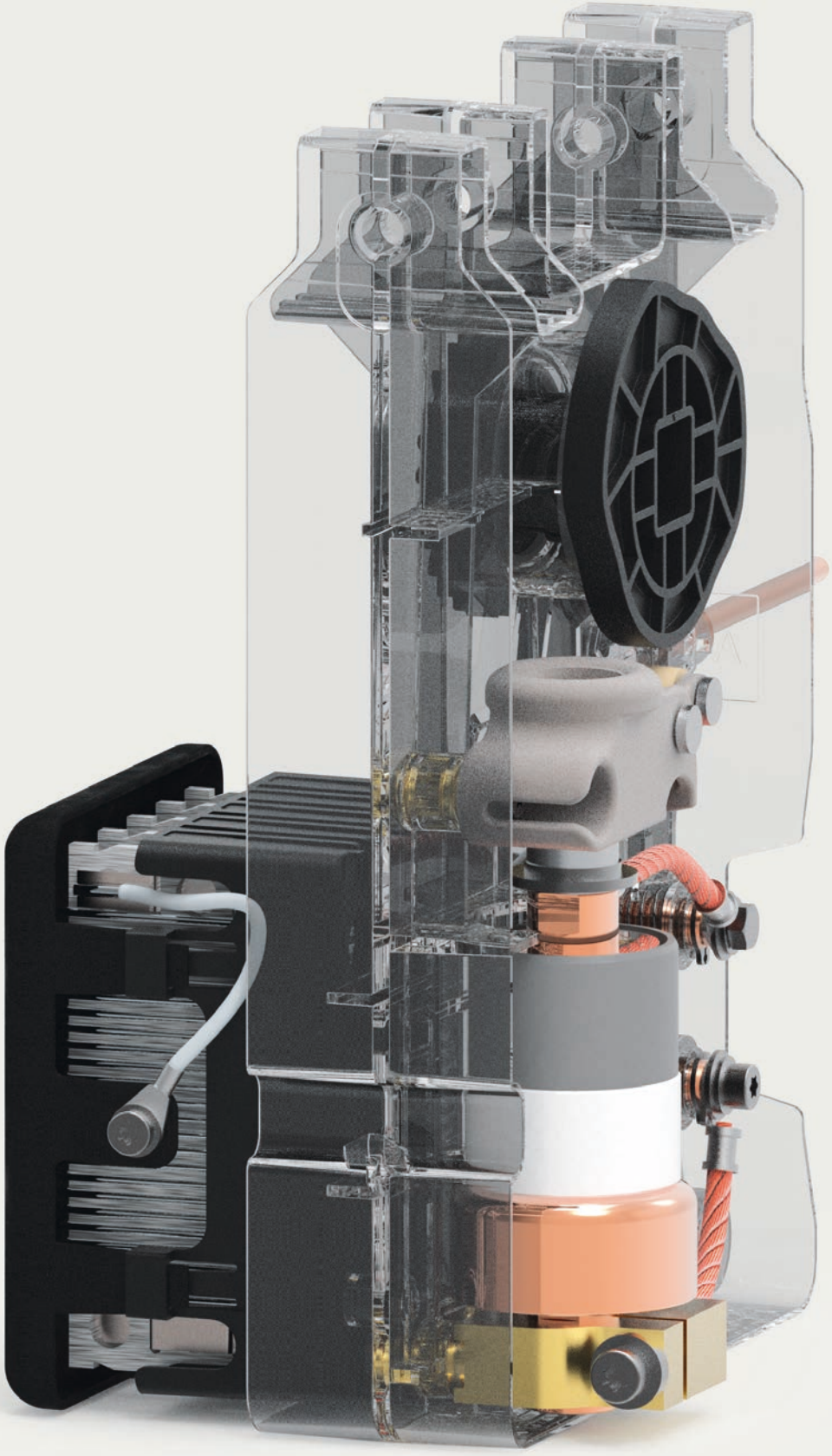
Process optimized. Plug & play.

ECOTAP® VPD® fits seamlessly into the **transformer manufacturer's** processes - from design and assembly to testing.

- The well-known high-speed resistor-type tap-changer principle allows the existing transformer design to be adapted with ease and at little cost
- Rapid delivery times due to small number of product variants (7 resistor variants across the entire performance range)
- The tap winding can be integrated both electrically and mechanically at any point in the transformer's winding
- Moderate amount of assembly work due to small number of parts and minimized wiring
- Suitable for all drying processes
- Suitable for all test fields (no additional inductive currents)
- Support from MR's global service network

ECOTAP® VPD® makes handling voltage regulation distribution transformers just as simple as conventional ones for **operators**.

- Available for transformers from all manufacturers
- The outstanding economic viability makes use in many applications possible
- The compact footprint allows existing transformers to be replaced with ease on-site
- The compact design of the controller allows it to be installed in one fuse panel
- Maximum longevity thanks to proven MR vacuum technology
- Maintenance-free for the entire life of the distribution transformer
- Satisfies the EU Ecodesign Directive because the transformer's loss class is not affected
- The large regulating range with fine steps provides a large application range without the risk of flicker
- Also suitable for alternative insulation fluids
- Convenient plug-based connection at the installation site
- The global MR network is available for training and servicing



MORE POWER, MORE VALUE.

Superior technology. Compelling economics.

The world's most compact on-load tap-changer for distribution transformers offering the largest range of services

- No change to footprint compared with conventional transformers in almost all power rating classes
- The compact controller will fit in anywhere, even on the busbar
- Market-leading range of features despite minimal dimensions

Maintenance-free and long-lasting with proven MR reliability

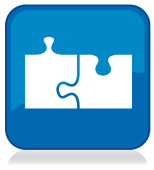
- Service life similar to that of a distribution transformer as there are no power electronics in the primary equipment
- No contamination of the transformer oil and no primary equipment maintenance thanks to proven MR vacuum technology
- Integration of all the experience we have gained from over 60,000 on-load tap-changers with vacuum technology

Maximum economic viability for the entire transformer/on-load tap-changer system

- No charges for servicing to the primary equipment – for the full life of the transformer; the secondary equipment can be replaced cheaply if necessary
- The high-speed resistor-type tap-changer principle avoids additional costs for losses energy
- The tried and tested vacuum technology is a significant addition to the functional scope of transformers for moderate additional costs compared with a non-regulated transformer

Ready for future requirements

- Already satisfies the requirements of the EU Ecodesign Directive for 2021
- Permits the use of synthetic and natural esters as insulating fluids
- Additional functionalities can be retrofitted economically thanks to the modular control concept



Perfect integration into the transformer manufacturer's processes

- Compatible with all common transformer designs, drying and test processes
- Electrical and mechanical connections in the transformer can be undertaken with conventional tools and work practices
- Only slightly more wiring compared with a non-regulated transformer and maximum flexibility in terms of winding arrangement

Uncomplicated commissioning – simple operation

- Commissioning and operation as for a conventional distribution transformer
- Can be parameterized and operated without a laptop
- Time-saving plug-based connection

OPERATING PUBLIC DISTRIBUTION GRIDS WITH STABLE VOLTAGES.

As well as a reliable supply of electricity, the customers of public distribution grid operators expect to be provided with a relatively constant voltage within a narrow bandwidth regulated by standards.

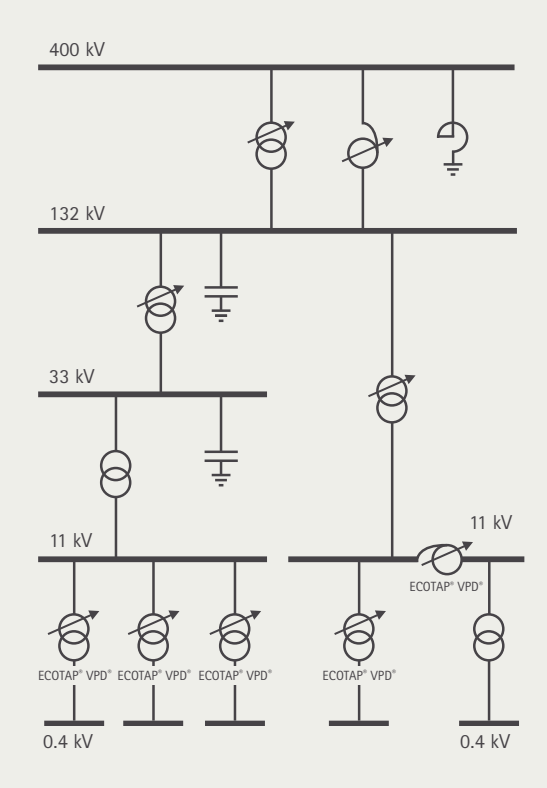
Otherwise the quality of the energy supply suffers, which may result in problems in equipment and processes and damage to electrical systems, potentially including a risk to life and limb. Depending on the topology and equipment of one's own grid, the voltage stability efforts of the upstream grid operator, the scope and behavior of demand and feed-in, and also the prevailing regulation regime, maintaining a stable voltage is a challenge for distribution grid operators.

In wide ranging grids with overhead cables, a weak short-circuit power, and huge increases in demand, as are commonly found in Asia and Africa, it is very hard to ensure a stable voltage supply. This is especially true if the upstream grid operator does nothing or very little to ensure voltage stability.

Complete voltage control for distribution grid operators

Voltage regulation transformers or line regulators with ECOTAP® VPD® give distribution grid operators direct access to tried and tested equipment, which they can use at a central point to stabilize the voltage for several low-voltage feeders regardless of the voltage in the upstream grid. Compared with capacitor banks, voltage regulation transformers or line regulators last much longer and permit finer regulation.

Whether a voltage regulation transformer or line regulator with ECOTAP® VPD® is the optimum solution depends on various factors including the size of the grid area to be stabilized.



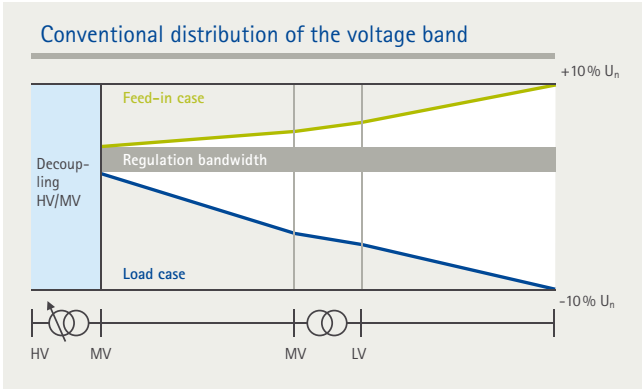
Thanks to proven MR vacuum technology, the relia-bility of the ECOTAP® VPD® is unique. In its performance class, it is also the only on-load tap-changer requiring no maintenance. Due to their extremely compact design, transformers with ECOTAP® VPD® can be used anywhere – also in pole installations, for example. The high economic viability of the complete transformer / ECOTAP® VPD® system makes this compact tap-changer in many cases the most efficient solution for stabilizing the voltage of a distribution grid.

ECONOMICALLY INTEGRATING RENEWABLE ENERGY AND NEW FORMS OF DEMAND INTO GRIDS.

Distribution grid operators face a difficult balancing act: On the one hand, they need to ensure a stable supply voltage in the medium and low-voltage grid and on the other hand, they need to integrate a growing amount of renewable energy (increase in voltage) and in the future also new types of demand (decrease in voltage).

In accordance with EN 50160, distribution grid operators are generally required to maintain a supply voltage of ± 10 percent around the nominal voltage at all points in the grid. As a result, the available bandwidth of 20 percent, starting from the HV/MV transformer regulated by the on-load tap-changer, needs to be distributed over the entire distance of the medium-voltage grid, the conventional distribution transformer, and the low-voltage grid to the building connection. It is not unusual for a maximum voltage rise to be permitted in such situations. In the low-voltage grid this is defined as 3 percent, due to renewable energy, and in the medium-voltage grid as 2 percent. The rest of the bandwidth is reserved for voltage drops and adjustment accuracies.

The huge growth in feed-in from renewable energy means that the permitted voltage band (in accordance with EN 50160) is more and more often at risk of being infringed. Likewise, new types of demand (E-mobility, heat pumps, etc.) are jeopardizing compliance with the voltage band in the other direction. As a result, distribution grid operators are being forced into expensive grid reinforcement measures, even though the thermal capacities of their equipment in the grid are far from being fully exploited.

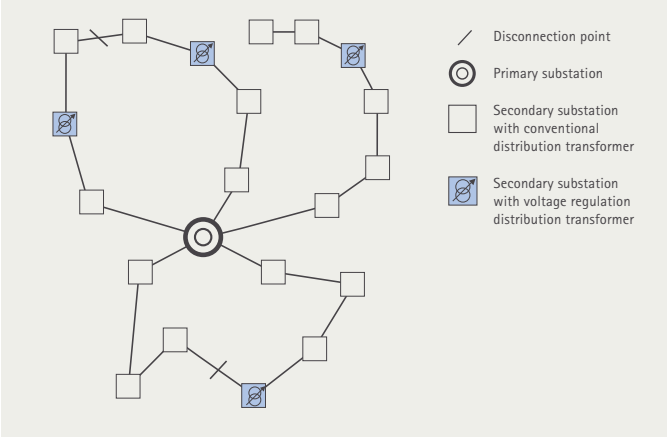


Making optimum use of grid capacity with voltage regulation distribution transformers

A voltage regulation distribution transformer, i.e. a distribution transformer with ECOTAP® VPD®, solves the crux of the problem – compliance with the voltage band – by dynamically adapting the voltage.

Thanks to the resultant decoupling of the low- and medium-voltage levels, the voltage band available in accordance with EN 50160 can be re-distributed and therefore used more effectively. Currently, this principle is primarily used to connect renewable energy; however, it can also be used to integrate additional demand into the existing grid.

Because this can increase the grid's ability to absorb power by up to a factor of 4, the other alternative of expensive grid reinforcement can be completely avoided or at least put on hold. First and foremost, the voltage regulation distribution transformer can be used to make greater and therefore more economic use of grid equipment.

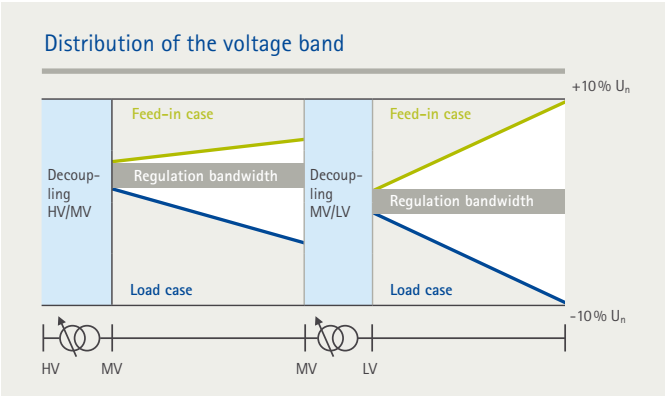


As well as avoiding infringements of the voltage band in low-voltage grids, voltage regulation distribution transformers can also be extensively and cleverly used in the medium-voltage grid to make the integration of feed-in and demand more economical.

On-load tap-changers are especially good solutions for cost-effectively integrating renewable energy and new forms of demand into the grid as their compact dimensions, zero maintenance, and long lives keep investment and operating costs down for distribution grid operators. A large regulating range coupled with fine steps also ensures that as much feed-in power or demand can be integrated into grids as possible without causing flicker as a result of excessive voltage changes.

Targeted use of voltage regulation distribution transformers with a focus on the low-voltage grid

Operating principle



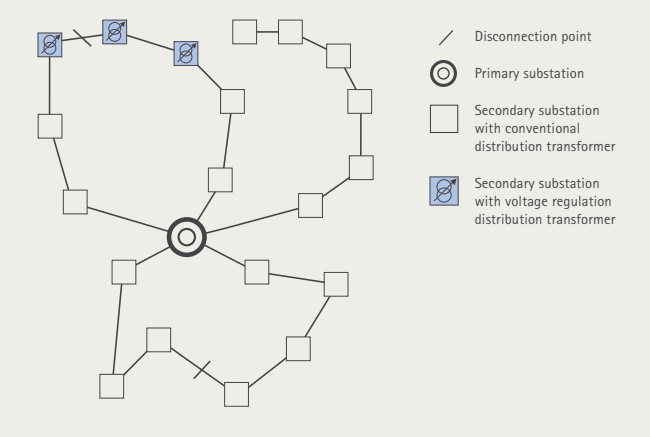
- Individual secondary substations are equipped with a voltage regulation distribution transformer, whereby the low voltage is decoupled from the medium voltage.
- The voltage band in the low voltage is re-distributed within the EN50160 requirements (± 10%)

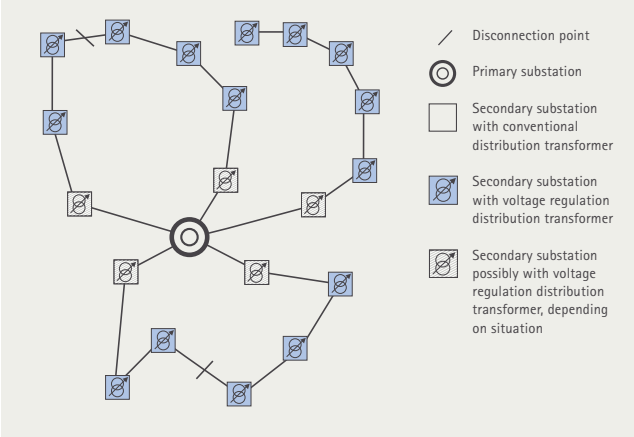
Scope of application

- Where there is a risk of the voltage band being infringed at the medium voltage by huge fluctuations in feed-in (e.g. wind turbines) or high irregular industrial demand
- Where there is a risk of the voltage band being infringed at the low voltage by volatile feed-in (e.g. large roof-mounted systems) or new kinds of consumers (e.g. E-mobility, heat pumps)

Advantages

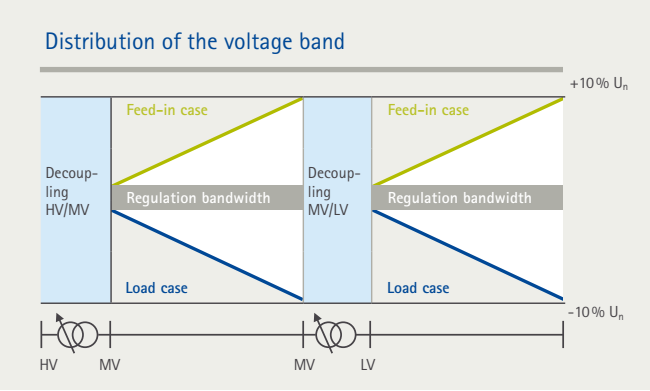
- Greater potential for feed-in and demand to be integrated throughout the low-voltage grid
- Avoidance or postponement of grid reinforcement measures in the low-voltage grid (running cables in parallel, locating new secondary substations, etc.)
- Increased planning certainty for all feeders of the secondary substation affected due to more potential for integration





Feeder-based use of voltage regulation distribution transformers with a focus on the medium-voltage grid

Operating principle



- Secondary substations at or beyond a certain distance from the primary substation are equipped with voltage regulation distribution transformers
- The voltage of the underlying low-voltage grids is decoupled from the voltage of the affected medium-voltage line or ring and kept within the requirements of EN 50160 by the voltage regulation distribution transformers
- As a result, higher voltage fluctuations in the affected medium-voltage grid are possible

Scope of application

Where there is a risk of voltage bands being infringed in a larger interconnected area at the medium-voltage level, e.g. at the end of feeders, due to large fluctuating or constant feed-in and/or consumers in the vicinity of the stations in question

Advantages

- Greater potential for feed-in and demand to be integrated into the medium-voltage grid and the underlying low-voltage grids
- Avoidance or postponement of grid reinforcement measures in the medium-voltage grid (running cables in parallel)

Use of voltage regulation distribution transformers **in all parts of the grid** with a focus on the medium-voltage grid

Operating principle

- All secondary substations not located in the direct vicinity of the primary substation are equipped with a voltage regulation distribution transformer
- The voltage of the underlying low-voltage grids is decoupled from the medium voltage and kept within the requirements of EN 50160 by the voltage regulation distribution transformers
- Higher voltage fluctuations are permitted in the medium-voltage grid affected and a further reduction in the desired voltage value at the HV/MV transformer is also possible

Scope of application

Where there is a risk of voltage bands being infringed in a larger interconnected area at the medium voltage as a result of excessive voltages from the high voltage or feed-in connected directly to the primary substation, which cannot be compensated for by the on-load tap-changer on the HV/MV transformer.

Advantages

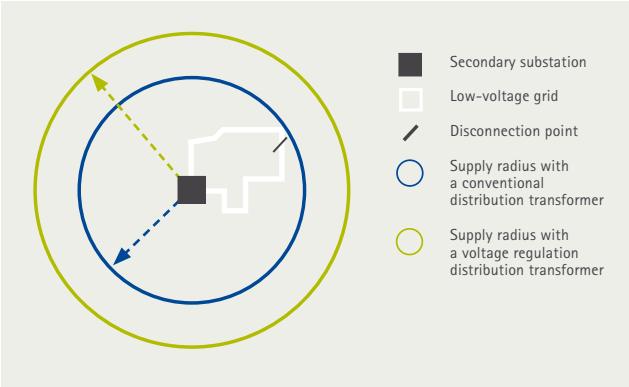
- Greater potential for feed-in and demand to be integrated into the high- and medium-voltage grid and the underlying low-voltage grids
- Avoidance or postponement of large-scale grid reinforcement measures in the medium-voltage grid or construction of another primary substation
- Avoidance or postponement of replacement of a HV/MV transformer with a transformer with a different transmission ratio or a transformer with a tap changer

SOURCE: AVACON AG

OPTIMIZING GRID TOPOLOGIES.

An efficient distribution grid has as little equipment as possible. This enables savings of both investment as well as operating expenses. Voltage regulation distribution transformers with ECOTAP® VPD® help to improve the efficiency of grid sections. Using them can reduce the total number of secondary substations.

The number of secondary substations needed for a grid area is determined firstly by the maximum demand to be covered and/or the maximum feed-in to be transported and secondly by the maximum possible distance between the secondary substation and grid connection points from a voltage standpoint. Voltage regulation distribution transformers dynamically adapt the voltage and permit a larger electrical supply radius around each secondary substation. In this way, even consumers or feed-ins, which are a great distance from the secondary substation can be connected.

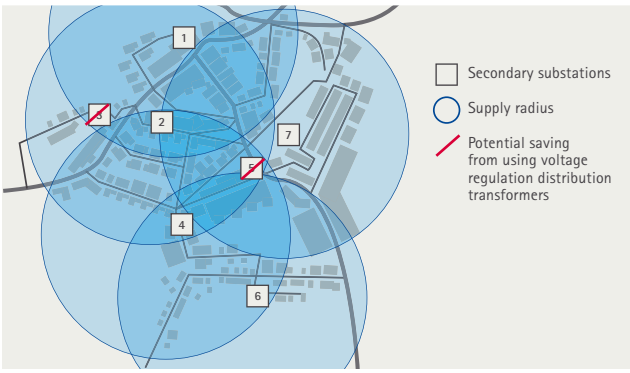


This allows the grid operator to combine two secondary substation or spares it from having to build a new secondary substation. If a supply job can be handled by one secondary substation alone, savings can be made in rent payments, station maintenance, and investments in replacement or new parts. The only requirement is that the one transformer is configured such that its performance is sufficient for the load and/or feed-in of the enlarged grid area.

In order to optimize grid topologies, the maximum regulating range of on-load tap-changers is of major importance because it determines the supply radius. Compact dimensions and zero maintenance further boost the economic viability of the optimization measure.

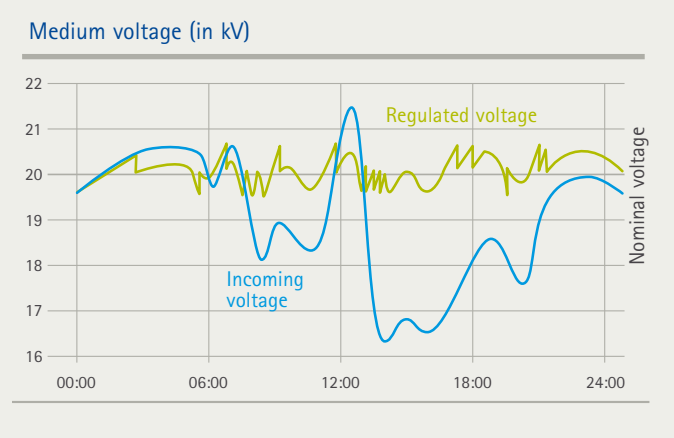
Example of how to optimize the grid topology using voltage regulation distribution transformers

A street village with around 1,500 inhabitants is supplied by 12 secondary substations, seven of which are located in the residential part of the village. Four of the seven secondary substations are more than 40 years old and are due for imminent modernization. By upgrading to voltage regulation distribution transformers with ECOTAP® VPD®, the electric supply radiuses of the secondary substations can be increased such that the village is supplied by five rather than seven secondary substations and quality isn't impaired. This halves the modernization costs. Land can also be returned to its owners. There are two fewer secondary substations to maintain.



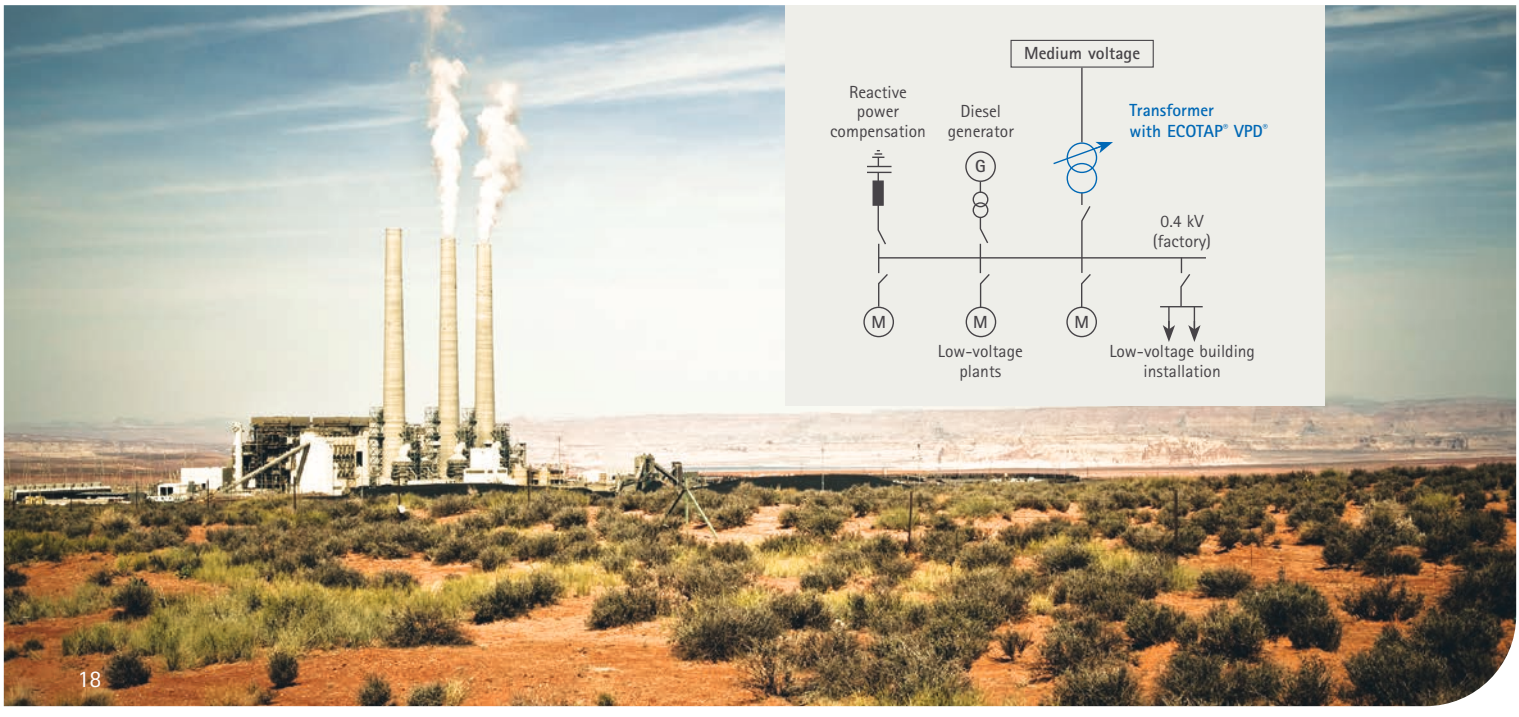
STABILIZING INDUSTRIAL PROCESSES IN VOLATILE GRIDS.

For industrial processes to run stably and reliably, they require a stable voltage supply within a narrowly defined band.



In grids with limited generator power, long distances or volatile consumers and producers, the supplying medium voltage may be subjected to large fluctuations in voltage. As a result, production cycles may be interrupted, motors may not start or control systems may crash. This can cause serious damage, especially in sensitive industrial processes. Hospitals are particularly critical in this respect. In addition to direct impacts on processes, frequent changes in voltage may also have a negative impact on the life of equipment.

A voltage regulation transformer with ECOTAP® VPD® in the industrial distribution grid ensures that consumers have a stable supply of voltage regardless of the volatility of the medium voltage. On-load tap-changers with a large regulating range which are able to reliably regulate even large fluctuations in the medium voltage for many years and without any maintenance are well suited to this application. Compact dimensions help to keep costs down because the voltage regulation transformer can be installed in place of the non-regulated one.



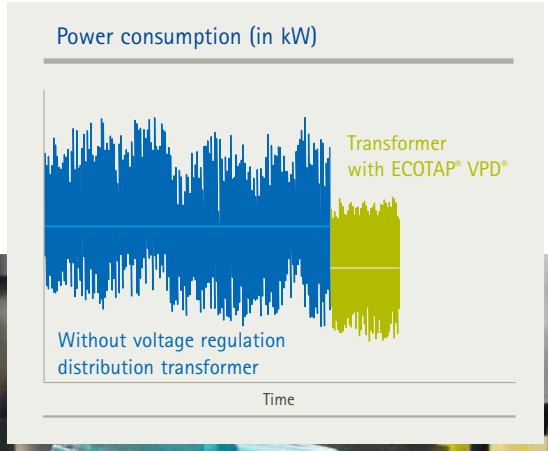
REDUCING ENERGY COSTS BY OPTIMIZING VOLTAGE.

Energy consumption for loads such as conventional, i.e. non-frequency-controlled motors, heaters or lighting is affected by factors such as the voltage with which the equipment is supplied.

If such equipment is supplied with a higher voltage than needed, e.g. because the medium voltage is higher than nominal voltage, the equipment consumes more energy than needed.

Using a voltage regulation transformer with ECOTAP® VPD® in the industrial distribution grid allows equipment to be supplied with a voltage actively optimized for it. This reduces energy consumption without limiting the equipment's function. The voltage regulation transformer's controller balances the voltage between what is available and what is ideal for consumption. Before the voltage falls to a level where equipment operation is at risk, the voltage regulation transformer intervenes and restores the voltage to a level which is ideal for equipment energy consumption. This enables energy costs to be reduced by up to fifteen percent.

Optimizing energy consumption requires on-load tap-changers with a large regulating range which can also be switched in small individual steps. This ensures that the actual voltage is always as close as possible to the optimum voltage from an energy consumption standpoint. Very compact equipment also has the advantage of being able to be installed without structural measures in electrical operating rooms, in place of the previous conventional transformer. To ensure an optimum return from the energy-saving measure, the solution also needs to be reliably operable for many years to come without any maintenance being required.



ECONOMICALLY COMPLYING WITH GRID CODES.

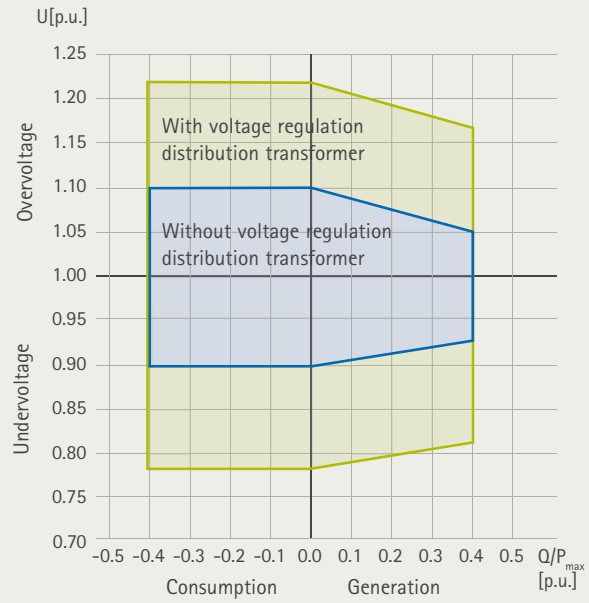
For integration into the grid, dispersed generation plants based on renewable energies (photovoltaics, wind, biogas) must meet the respective requirements of the grid operator in the form of grid codes.

Grid codes frequently oblige the manufacturers of dispersed generation plants to demonstrate the electrical properties of the systems and require type tests. The provision of reactive power, which depends on grid voltage, is particularly critical. Particularly when underexcited, the ability of the generation plants to provide reactive power is limited in the event of undervoltage. In cases where the requirements placed on providing reactive power are particularly demanding, making the required reactive power available can often only be accomplished either by oversizing the inverters or by requiring the generation plant to operate such that it reduces the amount of active power fed into the grid to suit the situation. Neither approach is particularly attractive; the former because it increases the system costs of the generation plant and the latter because it reduces the plant's capacity. Both lower the operator's return.

Voltage regulation transformers improve reactive power capability

By decoupling the secondary voltage from the grid voltage at the generator, voltage regulation transformers with ECOTAP® VPD® ensure that the generation plant is always supplied with its nominal voltage and use can thereby be made of full reactive power capability. Depending on configuration, full reactive power capability is available, for example, in a range of between +20 percent and -20 percent of nominal voltage.

An example of the reactive power provision in relation to the line voltage



The voltage decoupling made possible by the voltage regulation transformer means there is no need to oversize the inverters or reduce the amount of active power fed to the grid, which ultimately makes the generation plant more cost-effective. Alternatively, the headroom obtained by using the voltage regulation distribution transformer can also be used to operate an existing generation plant with a higher power rating.

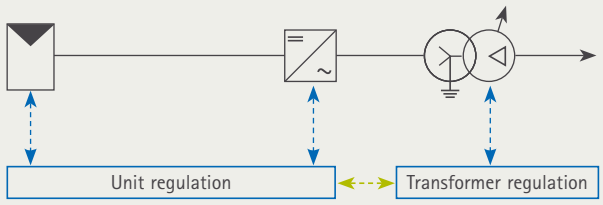
Another benefit of using voltage regulation transformers in generation plants is that there may then no longer be a need for an external reactive power compensation system, which would otherwise be required to comply with the grid codes. This measure also improves the cost-effectiveness of the generation plant.

Voltage regulation transformers can be integrated in all dispersed generation plants. Typical examples include wind turbines and photovoltaic parks.

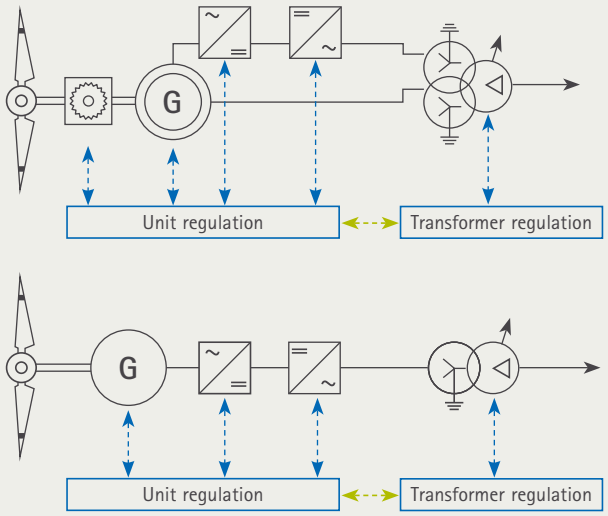
In the case of wind turbines, voltage regulation transformers can be combined with all driven train concepts, such as asynchronous generators or full-scale inverters. The voltage regulation transformer can either run on its own or be integrated in the generation unit's regulation system.

Given the very limited amount of space available, particularly in wind turbines, highly compact on-load tap-changers are essential. The cost-effectiveness of this application increases further with the size of the on-load tap-changer's regulating range and it must be possible, due to environmental and thermal load requirements, for the on-load tap-changer to be stably operated for many years in alternative insulating fluids without maintenance. Because time-based requirements usually also have to be satisfied in the provision of reactive power by generation plants, it is good if the on-load tap-changer can implement voltage changes in a matter of seconds.

Voltage regulation transformers in photovoltaic parks

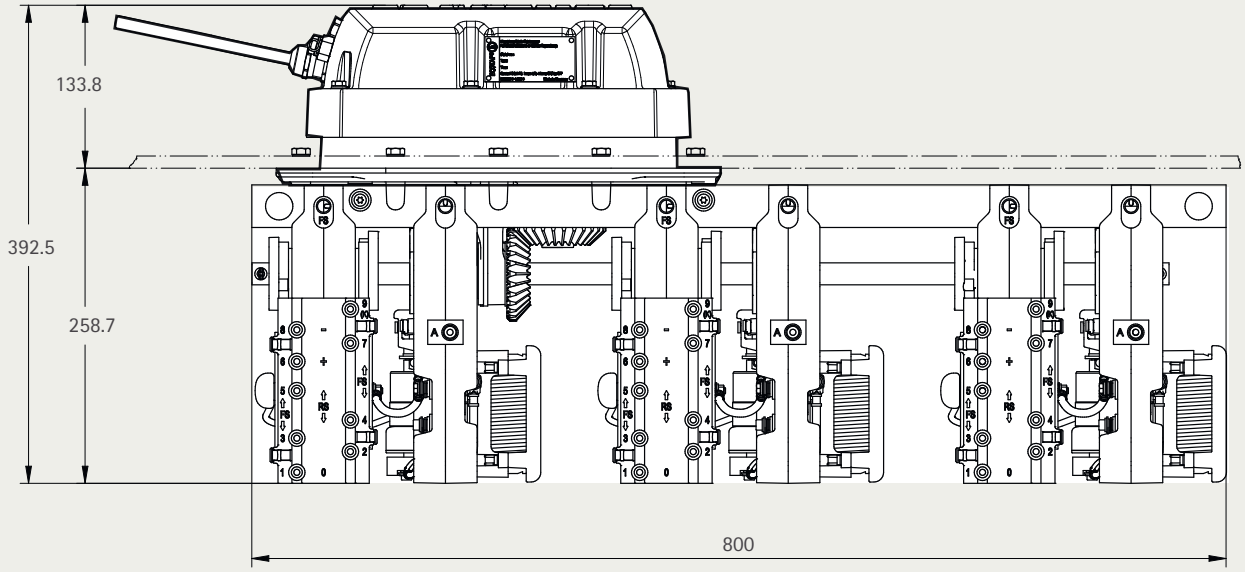


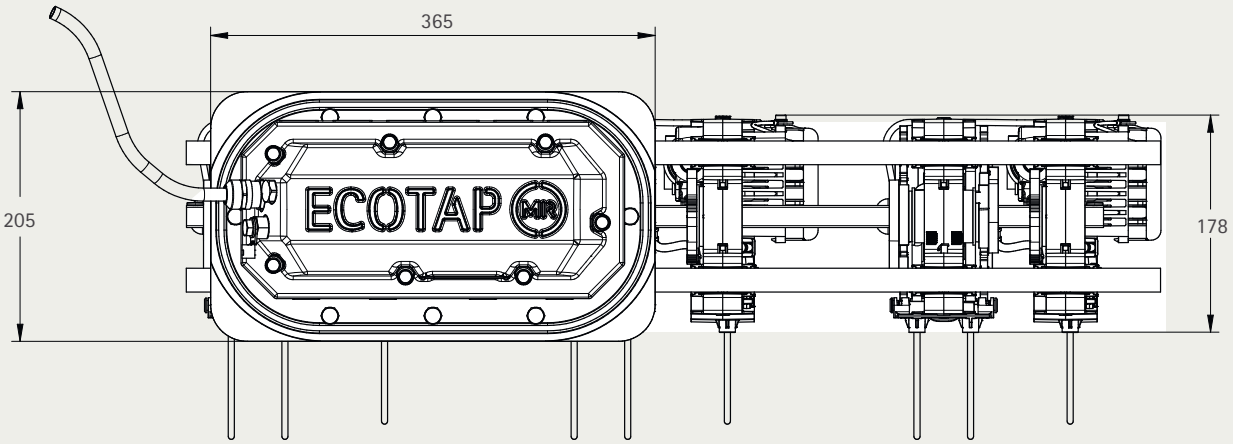
Voltage regulation transformers in wind turbines

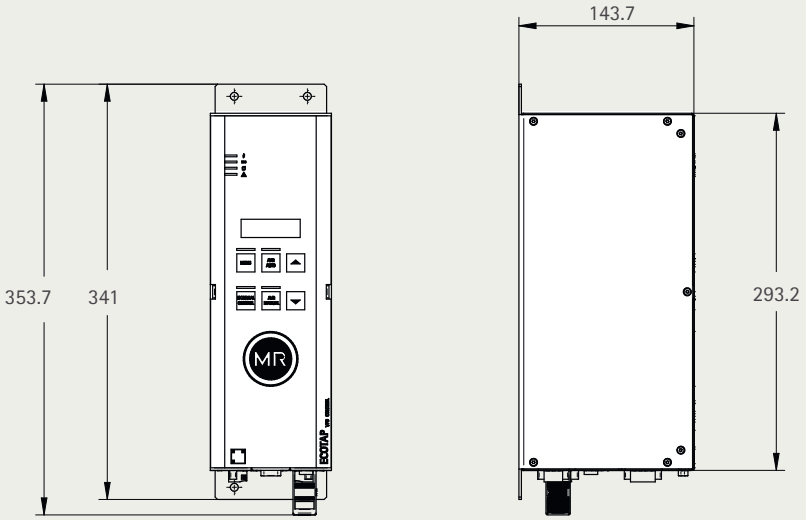


ECOTAP® VPD®.

Technical drawing of the 36 kV variant







TECHNICAL DATA.

On-load tap-changer	ECOTAP® VPD® III 30	ECOTAP® VPD® III 100
Number of phases	3	
Application	At any point in the winding	
Permitted transformer types	Free-breathing with oil conservator Totally oil-filled hermetic transformers (without gas cushion) Free breathing with air cushion only in combination with a special variant of the ECOTAP® VPD® (on request)	
Max. rated through-current	30 A	100 A
Max. rated step voltage	825 V	
Max. number of operating positions	9 operating positions without change-over selector 17 operating positions with change-over selector	
Highest voltage for equipment	36 kV, 40.5 kV	
Rated frequency	50/60 Hz	
Max. number of tap-change operations	500,000	
Permissible absolute pressure during operation	0,7...1,4 bar	

Motor-drive unit	
Runtime per tap-change operation	approx. 420 ms
Shortest gap between tap-change operations	3 s
Permissible ambient temperature during operation	-25°C ... +70°C
Protection class	IP66
Installation site	Indoors, outdoors

Control unit	
Permitted voltage range	100...240 VAC, 50/60 Hz
Note: Measured voltage is supply voltage	
Power consumption	Max. 345 VA
Internal fuse (F1)	Micro-fuse, 6,3x32 mm, min. 250 V, T4A
Permissible ambient temperature during operation	Continuous operation: -25 °C...+50°C Briefly (maximum of 2 h per day): -25°C...+70°C
Protection class	IP30
Installation site	Indoors, also suited to outdoor use in separate housing

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