GRIDCON® TRANSFORMER
VOLTAGE REGULATION FOR DISTRIBUTION GRIDS.

POWER QUALITY
STABLE VOLTAGES IN PUBLIC AND INDUSTRIAL DISTRIBUTION GRIDS.
A huge range of applications

Voltage regulation distribution transformers enable additional renewable energy sources to be integrated without the need for costly expansion work in the distribution grid. They also make it easier to connect wind and solar farms inexpensively, stabilize industrial processes, and help to keep energy costs low in industrial environments. What's more, thanks to actively selected voltage levels, they even make it possible for electrical distribution grids to operate in a way that keeps losses as low as possible.

Concept proven in transmission grids

The idea that the transmission ratio of a transformer can be adjustable rather than fixed goes back nearly as far as the concept of the transformer itself. Nowadays, in nearly every power transformer connected to high voltage or a ultra-high voltage level, you will find an on-load tap-changer. And there is nearly always a de-energized tap-changer in transformers connected to medium voltage, as well as in transformers connected to higher voltage levels. On-load tap-changers and de-energized tap-changers differ in that the former can dynamically change the voltage transmission in the transformer under load and therefore in line with the situation, whereas the latter can only adapt the voltage if the transformer is first de-energized.

Due to this fundamental functional difference between on-load tap-changers and de-energized tap-changers, dynamic voltage-regulating processes can now take place in transmission grids and therefore in and above the high voltage because the transmission ratios of the transformers can be adapted under load. In distribution grids, this option was not available up until now due to the reduced functional scope of de-energized tap-changers. In these grids, the transmission ratios between the medium and low-voltage grid were mostly fixed and could not be changed without temporarily shutting down the transformer.

However, with the current changes in the grids such as the sharp increase of decentralized energy supplied from renewable sources, the rise of electromobility and the use of heat pumps, as well as technical developments in voltage-regulating technology, this idea that has been in place for decades has started to change.

In grid planning and operation, the advantages that stem from dynamically adapting the voltage in the distribution grid and in the medium and low voltage grids are becoming more and more apparent. As is the case at the higher voltage levels, the on-load tap-changer is the device of choice here to enable the once static transformers in the distribution grid to regulate voltage under load.

Applications

- Economically integrating renewable energies
- Efficiently meeting grid connection codes for decentralized power generation plants
- Stabilizing industrial processes in volatile grids
- Reducing energy costs by optimizing voltage
VOLTAGE REGULATION FOR DISTRIBUTION GRIDS.

The unique advantage of the GRIDCON® transformer: It is just as small and reliable as non-regulated transformers. Its primary technology can even go for decades before it needs maintenance. It can replace existing transformers without the need to free up additional space.

Drive function

- Stepping motor
- Each tap-change operation lasts around 2 seconds
- Suitable for outdoor installation, IP65 level of protection

Transformation function

- Three-phase-current oil transformer
- 160 to 4,500 kVA (at 20 kV high voltage; maximum 2,250 kVA at 10 kV)
- 12 kV or 24 kV voltage range
- 3 phases
- With a width and depth no greater than a non-regulated transformer
- Maximum of 9 operating positions – alternatively, 5 or 7
- Free choice of regulating range which can be selected under load, e.g., ± 4 x 2.5 percent (maximum 600 V step voltage)
- Complies with the loss requirements stipulated by the EU ecodesign regulations for 2015 and 2021 (depending on the technical design)
Control and regulation function

- Autonomous voltage regulation based on the measured voltage (optionally also current or power)
- Option to include remote sensors in the regulation system
- Can be integrated into comprehensive regulation concepts
- Storage of power-quality measured data on an SD card (optional)
- Automatic, remote, and manual modes
- Ethernet interface
- Communication protocols IEC 60870-5-104, MODBUS TCP (optional)
- IP54 level of protection

On-load switching function

- On-load tap-changer following the proven reactor switching principle
- Arc quenching in specially developed vacuum interrupters
- Fitted in transformer tank above the active part
- Maintenance free for the entire life of the transformer (up to 700,000 tap-change operations)
- Regulation on the high-voltage side

Certified grid-regulating unit with proven operational safety, grid compatibility, and stable regulating functions (FGH product certification 2013, applicable standards IEC 60076, IEC 60214-1:2003, IEC 61000, EN 50160:2011)
THE IDEAL REGULATION CONCEPT FOR ANY REQUIREMENT.

The integrated voltage regulator permits fully autonomous operation. The GRIDCON® transformer independently adapts the voltage in the grid to the prevailing circumstances.

Various regulation concepts are available:

1. Fixed voltage set point for the low-voltage busbar
2. Load or current-dependent voltage set point for the low-voltage busbar
3. Fixed voltage set point for a remote sensor, critical grid node regulation
4. Optimization of the entire system using several remote sensors in the grid

The standard regulation concept is based on the three-phase measurement of the actual voltage on the low-voltage side of the GRIDCON® transformer and on regulation to a preset voltage set point (1). With an advanced version of this algorithm, it is also possible to dynamically adapt the voltage set point in line with the measured apparent power or current (2). For this, the direction of the current is taken into particular consideration.

As well as taking the measured values from the GRIDCON® transformer itself into account, the combination of remote sensors and special algorithms allows the voltage to be regulated with reference to one or several points away from the transformer. To do this, sensors which are available in various designs are used to transmit voltage data to the voltage regulator of the GRIDCON® transformer. This data is then factored in during the regulating process. What’s more, the sensors are able to save the measured data locally for future analyses.
Data can be transmitted between the sensors and GRIDCON® transformer via all current communication lines, such as GPRS, Powerline, and UMTS. In the simplest case, the voltage regulator attempts to maintain a preset voltage set point at a given sensor (3).

In more complex grids with several sensors, the information from different measurement points can be used to implement an overall optimum voltage in the grid using the voltage regulation in the transformer (4).

In addition to the regulation algorithms for which parameters can be set, individual alternative algorithms can also be implemented if necessary. Communicative integration into comprehensive regulation concepts is also possible using standard protocols.
MORE POWER,
MORE VALUE.

The ideal solution for operators of public and industrial distribution grids.

Maintenance free and long lasting
- The service life of the primary equipment corresponds to that of a non-regulated transformer
- Proven vacuum technology categorically excludes oil contamination through arcs and the primary equipment remains maintenance free
- The GRIDCON® transformer is the product of all our experience. We have been engineering on-load tap-changers since 1929, today using the superior vacuum technology. We have already supplied more than 50,000 of our vacuum-based on-load tap-changers, more than 12,000 of which use the reactor switching principle.

Maximum operational reliability
- Exclusion of critical operating statuses thanks to the reactor switching principle
- The GRIDCON® transformer has been tested in mechanical and electrical service life tests (well beyond the requirements of IEC standards)
- The GRIDCON® transformer is a certified grid-regulating unit with proven operational safety, grid compatibility, and stable regulating functionalities (FGH product certification 2013, applicable standards IEC 60076, IEC 60214-1:2003, IEC 61000, EN 50160:2011)

Low life-cycle costs
- Problem-free installation into existing compact stations since the dimensions of the GRIDCON® transformer match those of a non-regulated transformer
- 700,000 tap-change operations mean that maintenance is not required – over the life of the transformer; secondary equipment can be changed easily if required
- Depending on the technical design, operation is possible without additional losses in the regulation system

Designed with future requirements in mind
- The large regulating range of up to 24% in a 20 kV grid (up to 48% in a 10 kV grid) means that there is space in the grid for future feeds and loads
- Since parameters can be easily set for the regulation algorithms, the transformer can be flexibly adapted to future grid conditions
- Integrating remote sensors and incorporating the transformer into comprehensive regulation concepts are also possible at a later stage

Easy to commission and operate
- Commissioning hardly varies from that of a non-regulated transformer and can be performed by the same personnel
- The basic functions can be operated using large switches, keys, and display instruments, which can also be operated easily when wearing gloves
- The system performance is configured in detail using an intuitive web-based user interface for which no additional software is required
ECONOMICALLY INTEGRATING RENEWABLE ENERGIES.
Distribution grid operators are faced with a difficult balancing act: They must ensure a stable supply voltage in the medium and low-voltage grids while integrating an increasing number of renewable energy sources which cause the voltage to increase locally.

Within the voltage band permitted in accordance with EN 50160 (± 10 percent of the nominal voltage), renewable energy sources are allowed a maximum voltage swing of 3 percent in the low-voltage grid and a maximum voltage swing of 2 percent in the medium-voltage grid. The rest is reserved for voltage drops and adjustment inaccuracies.

Rapidly growing feed-in volumes are increasing the risk of the permitted voltage band being violated. Grid operators are being forced into expensive grid expansion work even though the capacities of their operating equipment is far from exhausted.

Optimally utilizing grid capacities with voltage regulation distribution transformers

A voltage regulation distribution transformer gets to the heart of the problem – maintaining the voltage band – by dynamically adapting the voltage. It decouples the voltage from the low-voltage and medium-voltage grid. As a result, for feed-in from renewable energies, a 13 percent (rather than a 2 percent) voltage swing is available in the medium-voltage grid and an 11 percent (rather than a 3 percent) voltage swing is available in the local grid. This usually eliminates the need for expensive grid expansion and in the few situations where this is not the case, network operators still gain time. In any event, using voltage regulation distribution transformers allows grid operating equipment to be more fully, and therefore more economically, utilized.
Grid connection codes often obligate manufacturers to prove the electrical properties of plants and carry out type tests. Reactive power availability, which is dependent on the line voltage, is often especially crucial. Particularly in the under-excited range, the reactive power regulating capacity of today’s power-generation plants is limited in the event of low-voltage due to system considerations.

**Voltage regulation distribution transformers extend the reactive power capacity**

By decoupling the secondary voltage of the generator from the line voltage, voltage regulation distribution transformers ensure that the power generation plant is supplied with the plant nominal voltage and that the full reactive power capacity can therefore be used. Depending on the design, the full reactive power capability is available in a range between +20 percent and -20 percent of the nominal voltage.

**Incorporating transformer regulation into unit regulation**

All drive-train concepts, such as asynchronous generators or full-scale converters, can be combined with voltage regulation distribution transformers that can either act autonomously or be integrated into the regulation system of the generator unit.

**Prepared for unit, plant, and product certification**

A product certification policy for grid-regulating units has already been developed and was implemented by the FGH at the end of 2013 with its issuance of the first product certificate for grid-regulating units in the world for the GRIDCON® Transformer. The policy can also be used for creating product certificates or as part of the unit/plant certificate for wind energy plants.
STABILIZING INDUSTRIAL PROCESSES IN VOLATILE GRIDS.

To enable industrial processes to run smoothly and reliably, they must be provided with a stable supply of voltage which fluctuates only within a narrowly defined range.

In grids with limited generator power, long transmission routes, or volatile consumption or feed-in, the medium voltage supplied can be subjected to severe fluctuations. This can interrupt production runs, prevent motors from starting up, or shut down control systems. What’s more, frequent changes in voltage can affect the service life of the operating equipment.

A voltage regulation distribution transformer in an industrial distribution grid can ensure that the customer is supplied with a stable voltage regardless of the volatility of the medium voltage. To do this, it compensates for the deviation between the medium voltage and the nominal voltage by changing its transmission ratio. If the medium voltage is too low, the transmission ratio is changed in such a way that a low voltage close to the nominal voltage is nevertheless available. If the medium voltage is too high, the process is the same but the transmission ratio is simply changed in the other direction.
REDUCING ENERGY COSTS BY OPTIMIZING VOLTAGE.

For loads such as motors, heaters, and lighting that are not frequency controlled, the voltage with which the machine is supplied is one of the elements that has an impact on the energy consumption.

If such a machine is supplied with a voltage that is higher than necessary – if the medium voltage exceeds the nominal voltage, for example – the machine uses more energy than it actually requires.

Using a voltage regulation distribution transformer in an industrial distribution grid means that machines are supplied with a voltage that is optimized for them, which reduces energy consumption without limiting the functionality of the machine. The control unit for the voltage regulation distribution transformer records the current voltage level and compares it with a voltage set using parameters for optimized energy consumption. If the voltage, and therefore the energy consumption, is too high, these are reduced by changing the transmission ratio in the transformer. Before the voltage drops so low that the machine may not be able to function, the voltage regulation distribution transformer intervenes again and increases the voltage so that it is as close as possible to the optimal voltage for energy consumption. Depending on local conditions, a reduction of energy costs by up to 10 percent can be realized.

Power consumption (in kW)

<table>
<thead>
<tr>
<th></th>
<th>With voltage regulation distribution transformer</th>
<th>Without voltage regulation distribution transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GRIDCON® TRANSFORMER
## TECHNICAL DATA – GRIDCON® TRANSFORMER.

<table>
<thead>
<tr>
<th>Transformer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rated power</strong></td>
<td>160 kVA to 4,500 kVA (20 kV with a delta connection on the high-voltage side)</td>
</tr>
<tr>
<td></td>
<td>160 kVA to 2,250 kVA (10 kV with a delta connection on the high-voltage side)</td>
</tr>
<tr>
<td><strong>High voltage</strong></td>
<td>Can be selected freely, maximum 24 kV voltage range</td>
</tr>
<tr>
<td><strong>Insulation level</strong></td>
<td>LI 125 AC 50</td>
</tr>
<tr>
<td><strong>On-load tap-changer</strong></td>
<td>5, 7, or 9 positions that can be changed under load</td>
</tr>
<tr>
<td></td>
<td>Free choice of arrangement, e.g., +6/-2, +4/-4, +3/-5</td>
</tr>
<tr>
<td><strong>Step voltage</strong></td>
<td>Can be selected freely, maximum 600 V, commonly 1.5%, 2%, or 2.5%</td>
</tr>
<tr>
<td><strong>Undervoltage</strong></td>
<td>Can be selected freely</td>
</tr>
<tr>
<td><strong>Insulation level</strong></td>
<td>LI – AC 3</td>
</tr>
<tr>
<td><strong>Winding material</strong></td>
<td>In accordance with customer requirements, Cu and Al possible</td>
</tr>
<tr>
<td><strong>Idling losses $P_0$</strong></td>
<td>$A_{n_0}$, $B_{n_0}$, $C_{n_0}$, or in accordance with customer requirements</td>
</tr>
<tr>
<td></td>
<td>Depending on the technical design, additional losses may be possible due to the switching device</td>
</tr>
<tr>
<td><strong>Short-circuit losses $P_s$</strong></td>
<td>$A_s$, $B_s$, $C_s$, or in accordance with customer requirements</td>
</tr>
<tr>
<td><strong>Short-circuit voltage</strong></td>
<td>4%, 6%, or in accordance with customer requirements</td>
</tr>
<tr>
<td><strong>Vector group</strong></td>
<td>In accordance with customer requirements</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>50 Hz</td>
</tr>
<tr>
<td><strong>Type of tank</strong></td>
<td>Hermetic corrugated-wall tank</td>
</tr>
<tr>
<td><strong>Type of cooling</strong></td>
<td>ONAN</td>
</tr>
<tr>
<td><strong>Max. ambient temperature</strong></td>
<td>40 °C</td>
</tr>
<tr>
<td><strong>Max. installation height</strong></td>
<td>1,000 m above sea level</td>
</tr>
<tr>
<td><strong>Protective devices</strong></td>
<td>In accordance with customer requirements</td>
</tr>
<tr>
<td><strong>Accessories</strong></td>
<td>In accordance with customer requirements</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Voltage regulator and control cabinet</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>3 AC 400 V</td>
</tr>
<tr>
<td>Current</td>
<td>1 A</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Test voltage to ground</td>
<td>2 kV / 1 minute</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>-20 °C... +50 °C</td>
</tr>
<tr>
<td>Interface</td>
<td>Ethernet</td>
</tr>
<tr>
<td>Protocol</td>
<td>IEC 60870-5-104, MODBUS TCP (optional)</td>
</tr>
<tr>
<td>Housing $(W \times H \times D)$</td>
<td>380 x 380 x 210 mm</td>
</tr>
<tr>
<td></td>
<td>400 x 500 x 210 mm</td>
</tr>
<tr>
<td></td>
<td>200 x 800 x 152 mm</td>
</tr>
</tbody>
</table>