

# THE SOLUTION FOR VARIABLE SHUNT REACTORS

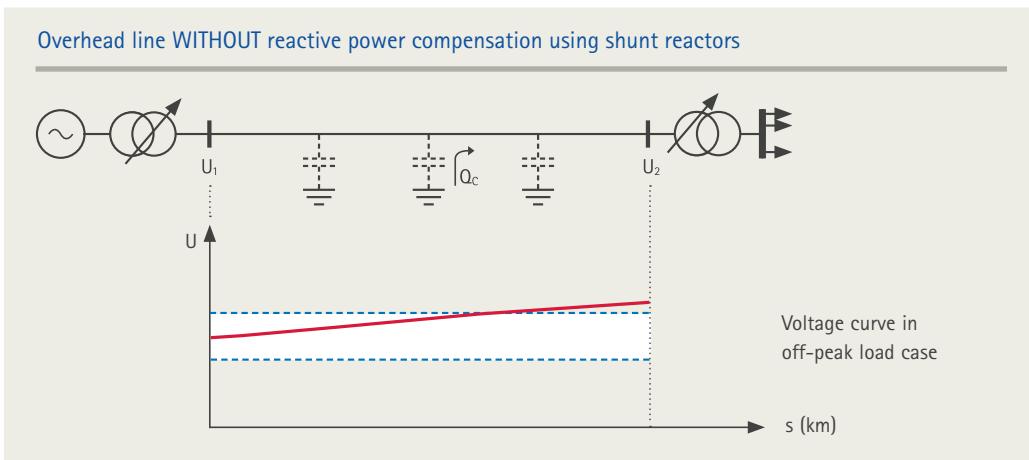


## VACUTAP® VRX FOR THE HIGHEST REQUIREMENTS FOR THE REGULATING RANGE.

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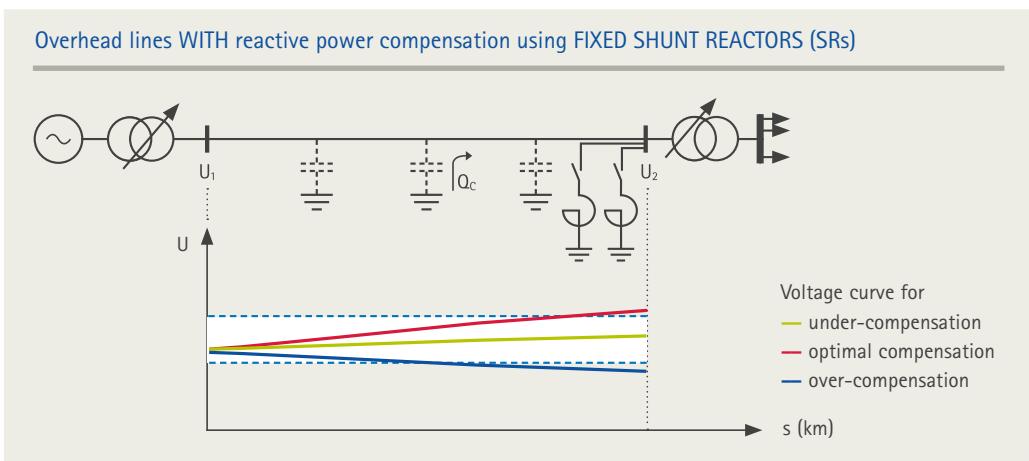


Effectiveness of shunt reactors and variable shunt reactors using an overhead line as an example.



At off-peak load times (e.g. no load in extreme cases), the amount of transmitted power is less than the natural load of the overhead line. Due to the inevitable line-to-ground capacitances, the overhead line has a capacitive effect. The lower the load, the greater this effect and the more the

voltage  $U_2$  at the end of the line increases (Ferranti effect). This may result in a violation of the voltage range and, in the worst case scenario, damage to the equipment. Efficient operation of the overhead line with minimal losses is also not always guaranteed.



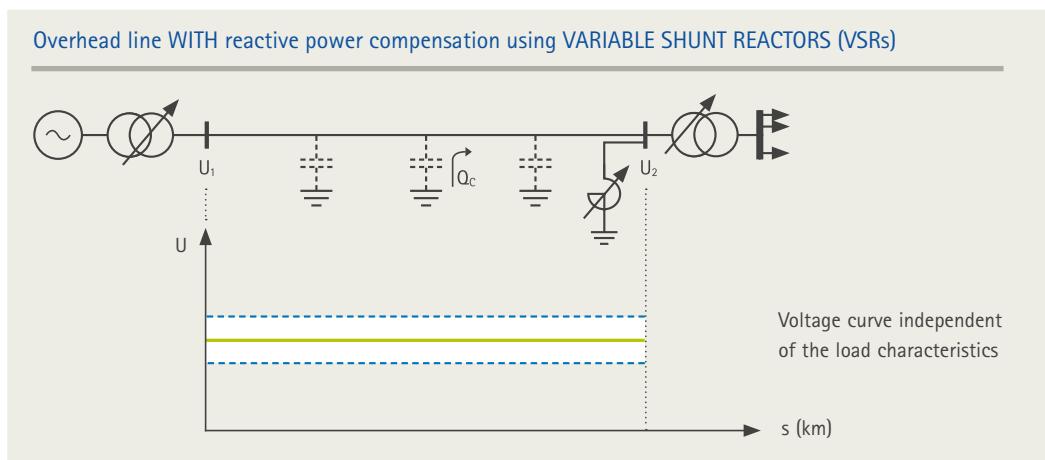
Using fixed shunt reactors can reduce both the higher voltage at the end of the overhead line and the transmission losses. In order to be able to adapt the reactive power compensation optimally to the situation in the grid, multiple shunt reactors working in parallel are necessary. These reactors must be switched on or off in various combinations as needed. The shunt reactors are usually switched on/off using circuit breakers. When using only one shunt reactor, on the other hand, the reactive power compensation is only optimal for a specific load case. If deviations from this load case occur, an over-compensation or under-compensation occurs, which results in an additional drop or rise in voltage along the overhead line, with the expected downsides.

The use of multiple fixed shunt reactors in parallel not only results in high investment and space requirements in the primary substation, but also leads to high maintenance costs, e.g. on the circuit breakers, which must be serviced after around just 10,000 operations.

In addition, switching the SRs of higher power to the grid using circuit breakers may lead to undesired critical stabilization operations in the grid.

A technically optimal and economical alternative is the use of a shunt reactor regulated using MR tap changers.

# VARIABLE SHUNT REACTORS WITH VACUTAP® VRX.



By developing the VACUTAP® VRX, MR is providing a unique and superior solution for being able to design shunt reactors so that they are equipped with an extremely wide regulating range of up to 80%, even at high voltage levels. Especially in challenging VSR applications with the need for a wide regulating range, the on-load tap-changer was frequently the limiting factor. The VACUTAP® VRX now provides a reliable and economical solution. This solution is based on the tried-and-true VACUTAP® technology, which is maintenance-free for up to 300,000 switching operations and provides maximum flexibility and efficiency in grid control.

Using a VACUTAP® VRX in a variable shunt reactor makes it possible to do the following:

- Avoid higher voltages at the end of the overhead line or in cable sections as well as damage to the equipment – using just one fixed unit.
- Increase the voltage capacity and grid stability, prevent violations of the voltage range and reduce the number of unplanned network interactions
- Use the finely graduated inductance levels provided by the on-load tap-changer over a large regulating range to implement a balanced reactive power reserve despite fluctuating load and in-feed characteristics. This implements optimal and reliable grid control.

- Minimize transmission losses and equipment loads using optimal reactive power regulation and increase the transmission capacity for active power.
- React to changes in the grid with flexibility thanks to the wide regulating range (grid expansion, additional integration of renewable power sources) and integrate the shunt reactor into other grid segments as needed.
- Use only one unit to provide technically and economically superior reactive power compensation. In comparison to the use of fixed shunt reactors, variable shunt reactors offer a better solution with reduced investment costs, space requirements and maintenance costs. This is because the number of components can be reduced. This minimizes life-cycle costs.

## Typical areas of use

- Long transmission cables
- Grid segments with cable sections
- Grid sections with large volatile supply of power, e.g. from renewable power sources
- Connection of off-shore wind farms
- Grids with significant fluctuations in the load and power supply characteristics

# VACUTAP® VRX FOR MAXIMUM FLEXIBILITY AND EFFICIENCY.

The VACUTAP® VRX combines the advantages of the tried and true vacuum technology with the highest requirements for the regulating range, such as with variable shunt reactors.

A stabilized reactive power reserve is crucial for reliable and efficient grid control with minimal losses. The reactive power requirement changes with the respective consumption and in-feed characteristics. These characteristics are subject to fluctuations that can be very significant depending on the day or season. The in-feed characteristics have become considerably more volatile, specifically due to the increased integration of renewable energies. These in-feed peaks, however, do not have to coincide with load peaks. In many cases, the generated electrical power is transported via overhead lines to centers of consumption.

Three basic load cases can be distinguished for overhead lines:

- The transmitted power corresponds to what is called the natural load of the line. In this case, no compensation measures are necessary with respect to voltage stability, as no significant change in voltage occurs along the line.
- The transmitted power is above the natural load of the line. The line has an „inductive“ effect in this case and a voltage drop occurs along the line.
- The transmitted power is below the natural load of the line. In this state, the line has a „capacitive“ effect and the voltage increases along the cable, i.e. it's higher at the end of the line than at the beginning of the line. This phenomenon is called the Ferranti effect.

This means that particularly in low-load cases, e.g. when idling (few or no consumers), the compensation of reactive power may be required in the case of long overhead lines and cable sections, in order to prevent dangerous overvoltages on the power line end and for cable sections. Otherwise, damage to the equipment may result.

As the grid utilization volatility increases, the importance of the reactive power regulation also increases in order to be able to guarantee a supply of power that

- is reliable
- has high-quality
- has minimal losses
- is economical

Capacitive reactive power regulation can be implemented using shunt reactors (SRs), which essentially create inductance that is integrated into the power grid in parallel to the loads and generators. Units that can be regulated are called variable shunt reactors (VSRs).

The same on-load tap-changers that have been successfully used to regulate power transformers for decades can be used for regulating VSRs.

By developing the VACUTAP® VRX, MR is adapting its tried-and-true solutions to meet new challenges. MR is providing a unique and superior option for designing variable shunt reactors in such a way that they are equipped with an extremely wide regulating range. This can offer both a technical and an economical advantage in operation. The ability to regulate the shunt reactor is achieved by designing part of the winding of the shunt reactor as a tap winding. This means that this part of the winding is

designed with taps that can be contacted using on-load tap-changers. As a result, it is possible to configure the inductance of the shunt reactor with precision and, therefore, to regulate the reactive power according to your needs. The reactive power absorption of the shunt reactor is inversely proportional to the square of the active windings, i.e. the smaller the number of active windings, the larger the reactive power absorption.



### Reduction in system costs and required space in the primary substation despite maximum regulating range.

- An extremely large reactive power regulating range can be implemented, e.g. up to 90% at the 110 kV system voltage level or 80% at the 420 kV level
- VACUTAP® technology, maintenance-free for up to 300,000 switching operations
- Superior selector service life with up to 1.2 million switching operations
- Compact and cost-effective – less equipment, less space
- Need for service and maintenance work significantly reduced

### Maximum operational safety

- Absolutely reliable arc quenching thanks to VACUTAP® Advanced Arc Control System
- Maximum protection from overvoltage situations in the grid for the diverter switch thanks to VACUTAP® Step Protection System®

Typical implementable reactive power regulating ranges

Rated voltage (kV)	Standard design (%)	Advanced design with VRX (%)
110	65	90
220	60	85
420	50	80
550	45	70
800	30	50

On-load tap-changer	VACUTAP® VRX I 651
Number of phases	1
Max. rated through-current $I_{rm}$ (A)	650
Rated short-time current (kA)	10
Rated duration of short-circuits (s)	3
Rated peak withstand current (kA)	25
Max. rated step voltage $U_{irm}$ (V)	12,000 (2 x 6,000)*
Step capacity $P_{sin}$ (kVA)	up to 2 x 3000
Rated frequency (Hz)	50...60
Operating positions	19 to 35
Motor-drive unit	TAPMOTION® ED and ED ISM®

\* > 9,000 V upon request

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IN5068254/00 EN – VRX – Shunt Reactors –  
F0340300 – 08/16 – uw –  
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THE POWER BEHIND POWER.

