MAINS LOAD OPTIMIZATION IN PHASE ANGLE

by thyristor power controller with VSC technology

Power controllers in VSC connection for regulated heating processes offer high dynamic and considerably advantages of cutting operating cost by saving electricity cost for the application.

Applications
• Electric boosting
• Glass applications
• Heating processes
• Melting processes

Thyro-P...VSC

This can be achieved by

- significant reduction of reactive power
- significant improvement of power factor
- considerable reduction of harmonics

With Thyro-P...VSC, a standard power controller is available for mains load optimizing and high dynamical heating processes.

3-stage VSC connection

As the following diagram shows significant improvements of power factor and reduction of reactive power compared to VAR (phase angle firing) mode can be achieved by VSC connection.

As of a modulation of 34 %, the power factor λ, e.g. for 3 stage VSC connection, is in the range of ≥ 0,9 and already from a modulation of 40 % the power factor is λ ≥ 0,97.

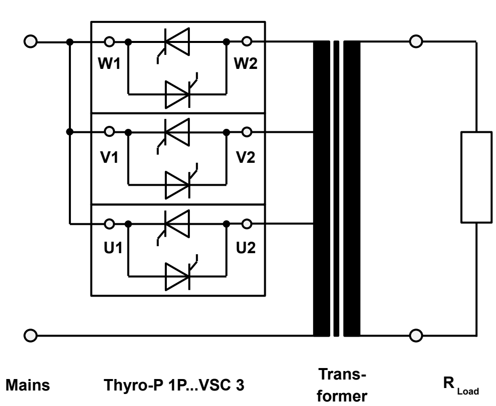

Illustration 1: Diagram of 3 stage VSC connection

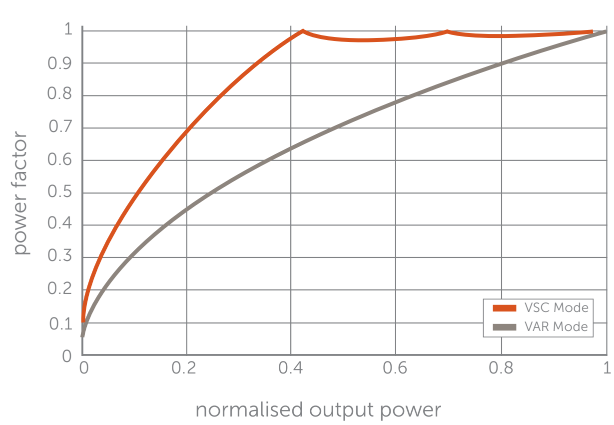

Illustration 2: Power factor in accordance to output effective power (modulation) of 3-stage VSC connection

VSC

Mains load optimization

Depending on the requirements and the load characteristics, even better characteristics of power factors are possible in modulation range below 40 % with appropriate projection.

Typically the energy provider brings to account costs for network access of reactive power not until a power factor of approx. < 0.9. In the range of 34 % to 100 % of load modulation (according to illustration 2), no network access costs accrue for reactive power.

Illustration 3 shows the arising reactive power in accordance to the required effective power (degree of modulation) – the field filled in grey (Q with Q/P > 50 %) above the line is typically subject to costs.

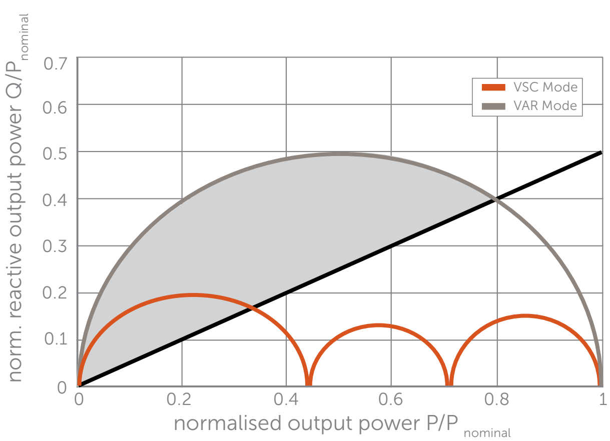

Illustration 3: Reactive power as function of the released effective power at 3-stage VSC connection

In the diagrams of illustration 2 and 3 can be seen that mains load optimization has been especially dimensioned for modulation range ≥ 40 %.

The according THDi values can be seen for evolving harmonics in the following diagram.

2-stage VSC connection

When applicable the slightly more cost effective 2-stage VSC connection can be used depending on the load characteristics and operating range as well as the values to be reached by power factor and reactive power.

Illustration 5 shows the diagram of a 2-stage, primary VSC connection. Further connection diagrams for VSC technology are shown in illustration 10.

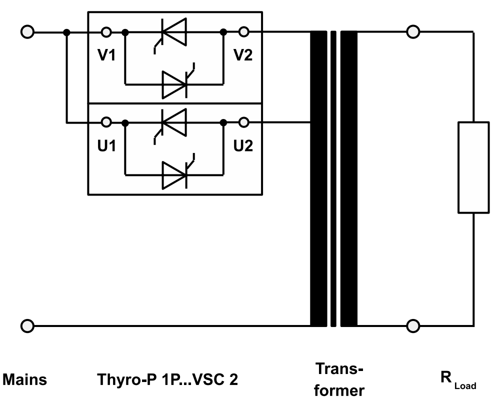

Illustration 5: Diagram of 2-stage VSC connection

The following illustration 6 shows the characteristic of the power factor for 2-stage VSC connection.

Starting from load modulation of > 53 %, the power factor is ≥ 0.9 so that typically no network access costs accrue for reactive power.

Illustration 7 shows the arising reactive power dependence to the needed effective power (degree of modulation) of a 2-stage VSC connection.

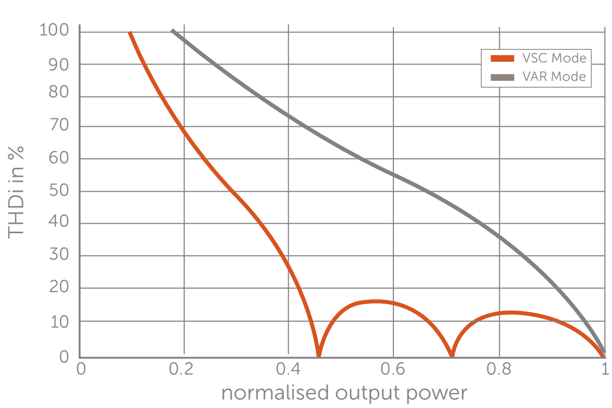

Illustration 4: THDi values of illustration 2 and 3 curves

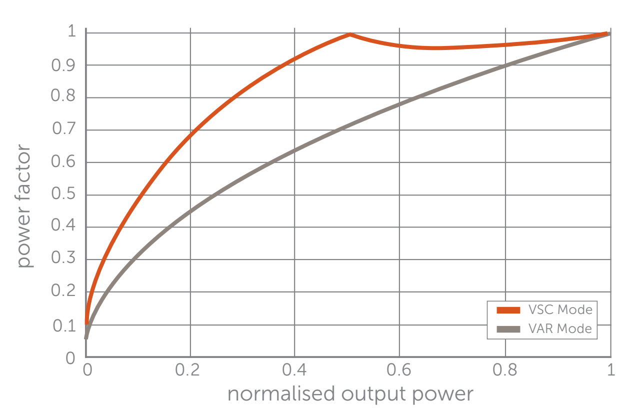

Illustration 6: Power factor in accordance to output effective power (modulation) of 2-stage VSC connection

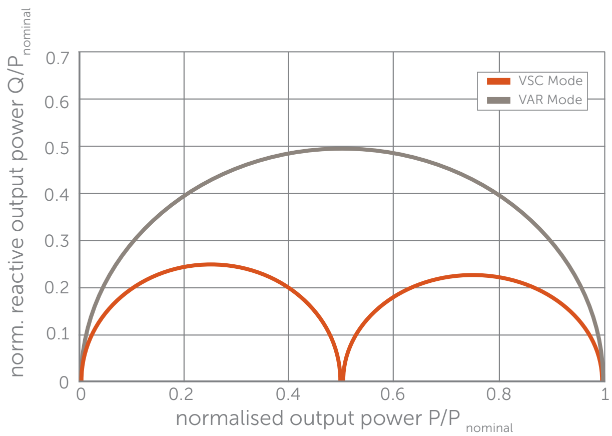

Illustration 7: Reactive power as function of released effective power at 2-stage VSC connection

Operating method of VSC technology

Using the example of a 2-stage VSC connection its operating method will be explained by which improvements can be achieved regarding reactive power, power factor and harmonics.

Illustration 8 shows the standard operating method of phase angle firing (VAR) and voltage-sequence-control (VSC). The blue curve is the load current trend over time in standard phase angle firing. The high edge is in combination with the distorted curve shape cause for the poor power factor, high ratio of harmonics as well as generated reactive power.

The red curve shows the current trend of a VSC connection which has the same effective value as the blue curve, however, as nearly sinusoidal curve and a low edge at the end of each half wave. That is why there is a very good power factor, a small ratio of harmonics as well as the small reactive power.

The VSC connection is controlled like a standard power controller by an effective setpoint. To control the 2 or 3 stage voltages of the transformer, the automatically control algorithm of the power controller is used.

Estimation of potential savings of operating costs

Estimation I:

In modulation range of the load it is possible to improve the medium power factor from 0.8 up to 0.9 or even better at the operating point. For a load which gathers 112 kW power this means a cost saving of approx. 2.698 € p.a. (at 100 % ED) of operating costs. The outcomes of this are payback periods < 0.5 years (for 2-stage VSC) and accordingly < 1.2 years (for 3-stage VSC).

By improving the power factor, the apparent power decreases in the system from 140 kVA to 125 kVA so that only a small transformer is necessary. By this influence the capital expenditure will decrease for new systems. If a transformer does already exist it will be less stressed so that further components could be connected to it.

Due to smaller currents of 240 A instead of 280 A, it can be reviewed if smaller unit sizes are applicable for further components to save additional investment costs.

If the power controller operates in a system with a total power factor of λ < 0.9, then the total power factor of system itself improves as well. Thus savings of reactive power costs are practical by using VSC connection for the whole system.

The following diagram can be used to estimate the variable reactive power cost and respectively possible savings by improving the power factor if the variable reactive power costs are calculated starting from a ration of Q/P > 50 %.

The curve is standardized for effective power of 100kW which is operating 100 % per year. Costs for reactive power are assumed to be 1.00 ct/kvarh. Therefore the reactive power costs are linear for a real application (with Q/P > 50 %) and can be easily calculated.

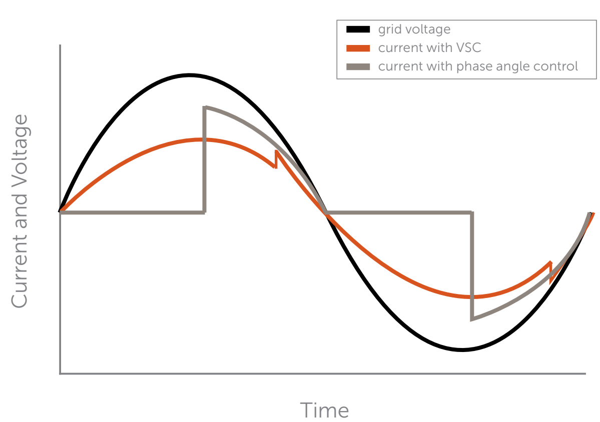

Illustration 8: Comparison of phase angle firing (VAR) and VSC (Voltage-Sequence Control) with same effective current value

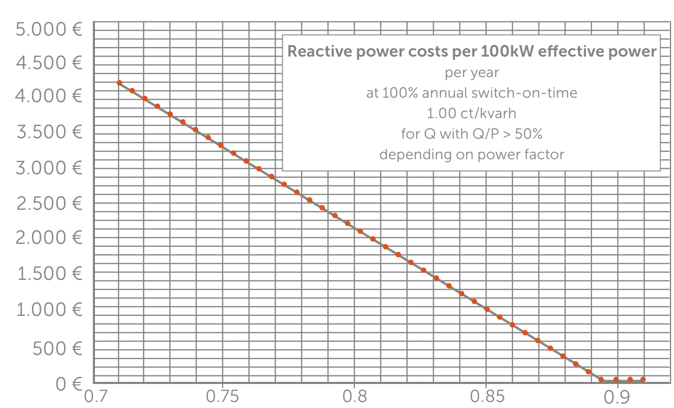

Illustration 9: Example for standardized reactive power costs

Estimation II:

Heater of 1000 kW power would be used with a power factor λ of 0.83, which results in costs of approx. 15,000€ p.a. according to illustration 9. With an improvement of λ = 0.9 the cost savings would be 15,000 € p.a. for each heater.

Variations of VSC connections

Besides the option to realize 2- or 3-stage VSC connections, Thyro-P 1P...VSC offers the feature to alternatively use it in primary or secondary connections.

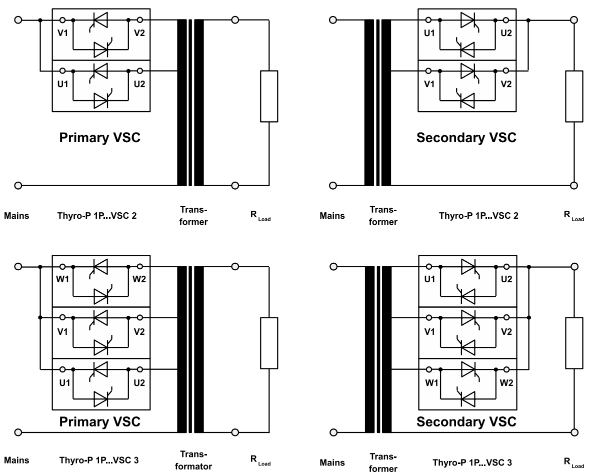

Illustration 10: VSC connection options

If the power controller is directly connected to the mains, that means prior to the transformer, then it is a primary VSC connection. If the power controller is after the transformer that means directly on the load then it is a secondary VSC connection.

VSC type range - Technical data

The type range Thyro-P 1P...VSC 2 and ...VSC 3 is available for rated voltage of 500 V and 690 V.

- Type voltage 400/500 V, 690 V
- Network frequency 47 Hz to 63 Hz

Type currents of 500 V series:

- 16 A/37 A/75 A/110 A
- 130 A/170 A/280 A
- 495 A/650 A/1000 A
- 1500 A/2100 A/2900 A

Type currents of 690 V series:

- 80 A/200 A/300 A/500 A
- 780 A/1400 A/2000 A/2600 A

Type of connection:

- primary VSC, 2-stage, 3-stage
- secondary VSC, 2-stage, 3-stage

Operating mode VSC_VAR:

- VSC with VAR (phase angle firing)

Control modes:

- U, U^2, I, I^2, P

Interfaces – as standard Thyro-P:

- LBA-2/bus/analog I/O/relays

UL/UR certificate:

500 V type range

- UL 16 A/37 A/75 A/110 A/130 A/170 A/280 A
- UR 495 A/650 A

690 V type range

- UL 80 A/200 A
- UR 300 A

Transformer specification

If a Thyro-P 1P...VSC power controller is installed for the first time then the electric transformer specification can be provided by Advanced Energy on request in accordance with the user. Therefore further specifications are required, e.g. the power factor λ to be achieved.

VSC connection for loads of alternating current

The named type ranges are designed for 1-phase applications. VSC connections for alternating current are available on request.

Remark:

The power factor λ = |P| / S is often referred to as cos φ by mistake, even though cos φ is only specified for sinusoidal quantities.

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