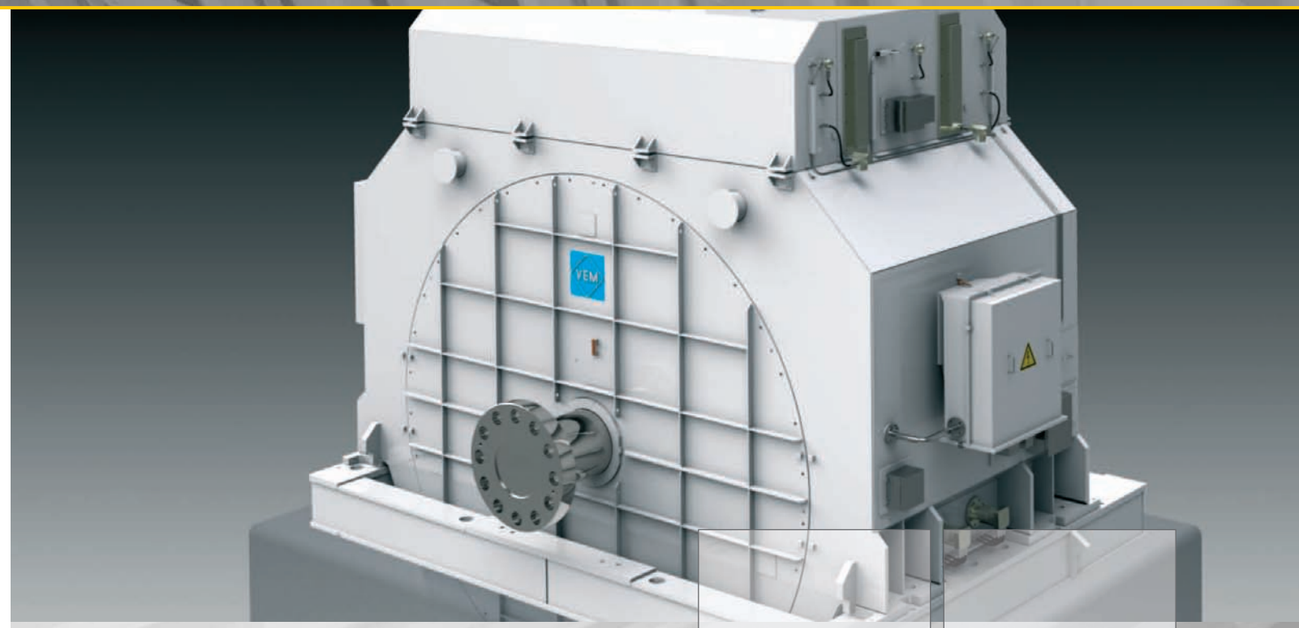
arture graphic design

Three-phase high-voltage compressor motors

asynchronous 500 – 22,500 kW
synchronous 2000 – 46,000 kW



Asynchronous motors

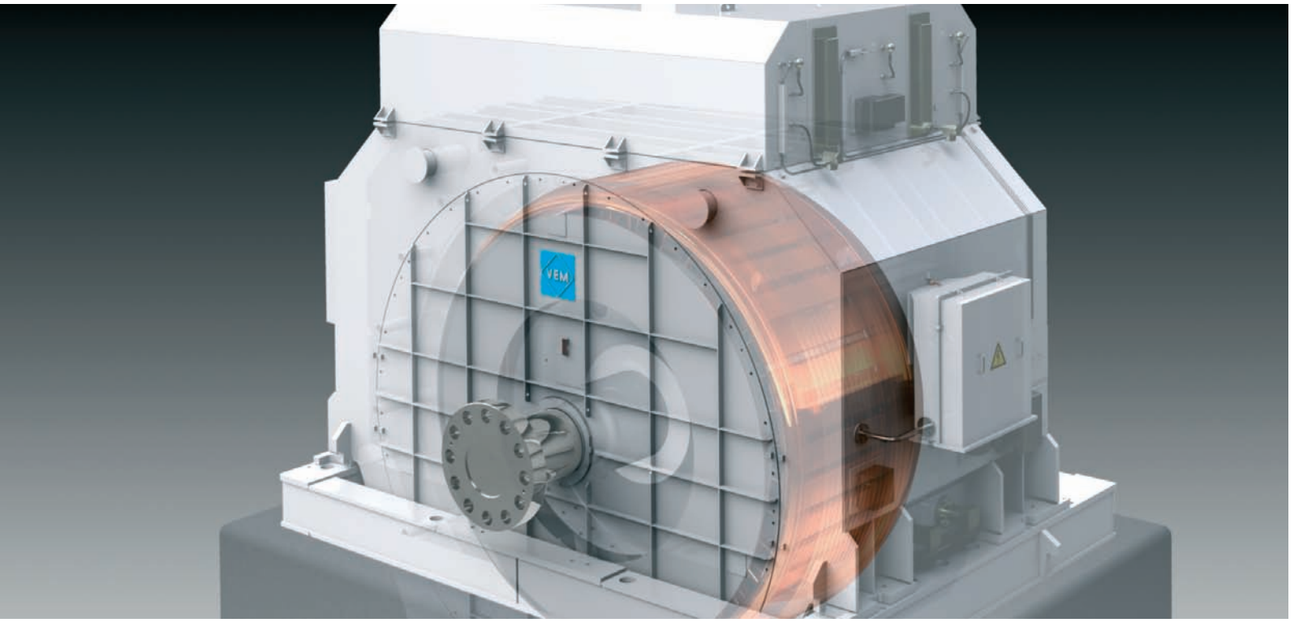
Synchronous motors

VEM Sachsenwerk GmbH
Pirnaer Landstrasse 176
01257 Dresden
Germany

Contact: Dr. Stefan Eberl
Phone: +49-(0)351-208-1439
Telefax: +49-(0)351-208-3505
E-Mail: eberl@vem-group.com
Homepage: www.vem-group.com

A **world** full of **motion**

SWD/03-173 E/0111 GD Printed in the Federal Republic of Germany. Changes reserved.



Contents

Preface

No matter whether they are used in power stations, in oil and gas industry or in plastic processing industry – high-performance compressors are used in many industry sectors for different systems. Since they usually are the heart of the production line, their drives have to be not only particularly reliable and durable, but they also have to be operated with energy efficiency.

VEM Sachsenwerk manufactures high-voltage asynchronous motors as well as synchronous motors for compressor units, which comply with these high requirements. We offer specific individual solutions for drives with a large range of modifications.
.

These include among others water-cooled motors or inverter-fed drives. They are characterised by reliability, maintainability, modular design, more efficient use and lower noise emissions. A solid construction concept guarantees a higher adaptability, in order to be able to respond to individual customer preferences.

We guarantee you customer-specific solutions of high quality.

The specific characteristic features are:

- Long service life of the winding and high allowable switching rate due to the application of the universal insulation system VEMoDUR have been available for decades of the operational experiences
- Design of the motors with 20% thermal reserve (insulation class F / utilisation B)
- Shatterproof design of the terminal boxes
- Good mounting conditions due to an advantageous mass-performance ratio
- Cost-efficient, simple reserves due to design of the motors according to the modular system
- Minimum maintenance, particularly with brushless excitation design
- More efficient use due to electro-magnetic optimisation
- Delivery of the excitation devices for brushless and slip-ring machines with automatic synchronisation and with a protection for asynchronous operation

All compressor motors are designed to customer specifications in order to comply with the special application criteria.

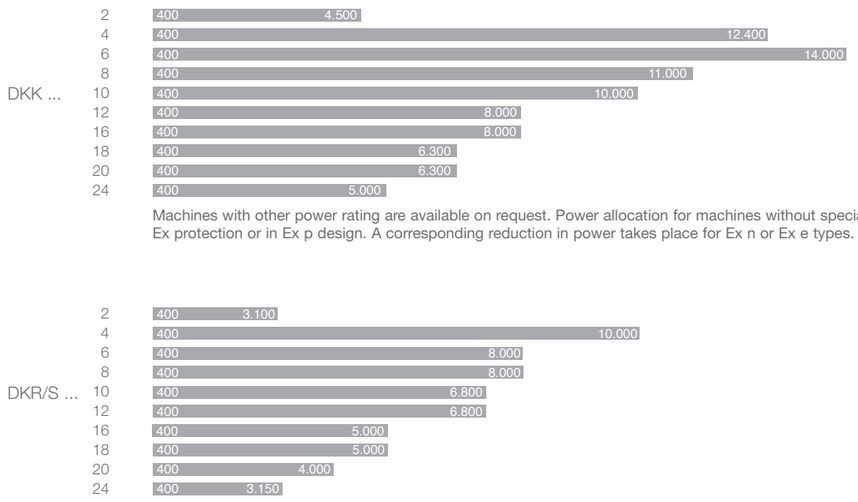
The catalogue contains general technical explanatory notes. Individual requirements must be handled separately. The technical specifications of the basic series can be ordered additionally by VEM.
We request interested parties to contact our sales department and VEM sales offices as well as VEM offices.
Orders require our written confirmation.

Note:
We always strive to improve our products continuously. Designs, technical specifications and drawings may be modified. Such modifications are only binding after written confirmation by the supplier.

1. Product range overview

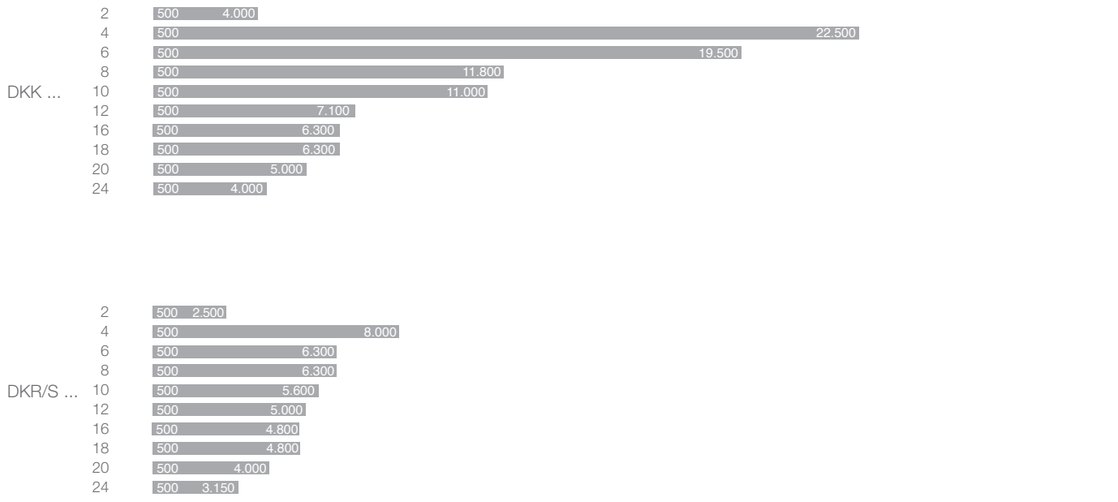
1.1 Asynchronous motors

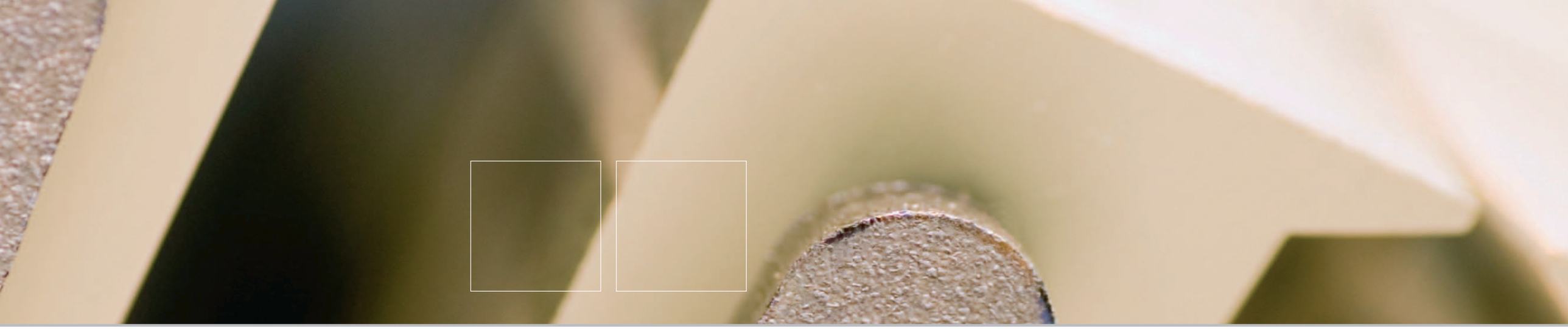
Asynchronous compressor motors 6 kV; 50 Hz; Air-water cooler



Machines with other power rating are available on request. Power allocation for machines without special Ex protection or in Ex p design. A corresponding reduction in power takes place for Ex n or Ex e types.

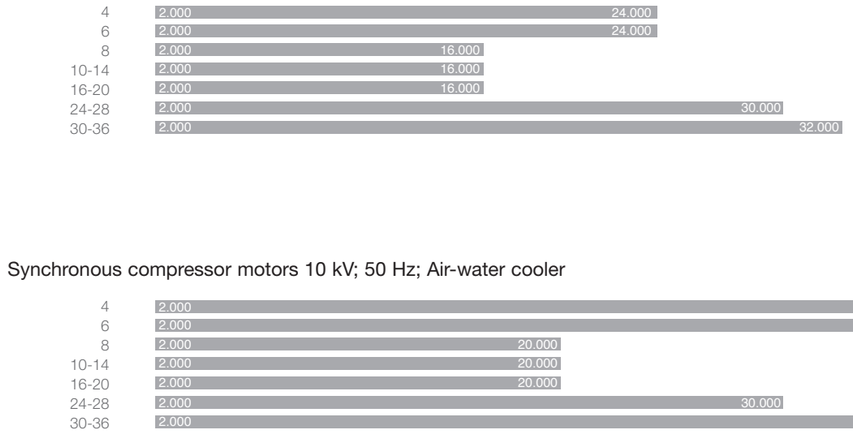
Synchronous compressor motors 10 kV; 50 Hz; Air-water cooler





1.2 Synchronous motors

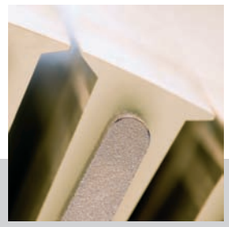
Synchronous compressor motors 6 kV; 50 Hz; Air-water cooler



Synchronous compressor motors 10 kV; 50 Hz; Air-water cooler

Number of poles

Power in kW



www.vem-group.com

2. Classification of types

Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	D	T	K	V	Y	4	3	3	6	3	0	W	S	

The classification of types of Sachsenwerk consists of letters and figures.

Letters	*Position*	*1-5*
Figures	*Position*	*6-9*
Figures/letters	*Position*	*10-14* *(variable, depending on the machine type)*

1 **Type of current**
E = Single-phase alternating current
D = Three-phase alternating current
M = Polyphase alternating current

2 **Machine type**
A Alternating current - Asynchronous - Generator
K Alternating current - Asynchronous - Motor with a squirrel-cage rotor
B Alternating current - Asynchronous - Motor with a slip-ring rotor with BAV (a brush lifting device)
S Alternating current - Asynchronous - Motor with a slip-ring rotor without BAV
G Alternating current - Synchronous - Generator with slip rings
R Alternating current - Synchronous - Generator without slip rings
M Alternating current - Synchronous - Motor with slip rings
T Alternating current - Synchronous - Motor without slip rings
C Alternating current - Commutator motor
U Alternating current - Single-housing transformer

3 **Type of cooling, type of protection class**
E Open-circuit cooling / Self-cooling without additions (IP00; IP10; IP20; IP21; IP22; IP23)
A Open-circuit cooling / Self-cooling with additions (IP23; IP24)
F Open-circuit cooling / Self-cooling pipe connection with an internal ventilator (IP44; IP54; IP55)
L Ventilation / External cooling, an additional ventilation unit or a pipe connection (IP00; IP10; IP20; IP21; IP22; IP23; IP24)
B Ventilation / External cooling, pipe connection (IP44; IP54; IP55)
R Circulation cooling / Self-cooling with air-air cooler (IP44; IP54; IP55)
K Circulation cooling / Self-cooling with air-water cooler (IP44; IP54; IP55)
S Circulation cooling / External cooling with air-air cooler and an additional ventilation unit (IP44; IP54; IP55)
M Circulation cooling / External cooling with air-water cooler with an additional ventilation unit (IP44; IP54; IP55)
N Circulation cooling / Own or external cooling with gas as coolant (except for air); all degrees of protection
O Surface cooling / Self-cooling with cooling holes (IP44; IP54; IP55)
C Surface cooling / Self-cooling with cooling fins (IP44; IP54; IP55)
P Surface cooling / Self-cooling without a ventilator (IP44; IP54; IP55)
W Surface cooling / External cooling with water cooling jacket (IP54)
V Surface cooling / External cooling with an additional ventilation unit (IP54)

4 and 5 **Design type** (encoded) Arrangement of bearings, divergent voltage and frequency, Ex protection, model, heavy starting etc.

6 and 7 **Axle height** (encoded)

8 and 9 **Length of the laminations** (encoded)

10 and 11 **Number of poles**

12 to 14 **Additional letter for revision grade and special conditions**
Code letters for special winding designs

3. Standards and regulations

The motors comply with the applicable DIN standards and the DIN VDE regulations (VDE – Association of German Electricians). For the basic designs these are especially DIN EN 60034 (VDE 0530) and IEC 60034 with the following parts:

Part 1 Dimensioning and operating behaviour
DIN EN 60034-1 (VDE 0530-1) - IEC 60034-1

Part 2 Process for definition of losses of the efficiency rate
DIN EN 60034-2 (VDE 0530-2) - IEC 60034-2

Part 5 Classification of types of protection
DIN EN 60034-5 (VDE 0530-5) - IEC 60034-5

Part 4 Process for determination of the parameters of synchronous machines via measurements
DIN EN 60034-4, VDE 0530-4, IEC 60034-4

Part 6 Classification of cooling procedure
DIN EN 60034-6 (VDE 0530-6) - IEC 60034-6

Part 7 Classification of types
DIN EN 60034-7 (VDE 0530-7) - IEC 60034-7

Part 8 Designation of connections and direction of rotation
DIN VDE 0530-8 - DIN EN 60034-8

Part 9 Limit values for noise
DIN EN 60034-9 (VDE 0530-9) - IEC 60034-9

Part 14 Mechanical vibrations ...
DIN EN 60034-14 (VDE 0530-14) - IEC 60034-14

Part 15 Rated surge voltages ...
DIN EN 60034-15 (VDE 0530-15) - IEC 60034-15

Part 16 Excitation system for synchronous machines
DIN EN 60034-16… (VDE 0530-16) - IEC 60034-16

Part 18 Functional evaluation of insulation systems
DIN EN 60034-18 (VDE 0530-18) - IEC 60034-18

as well as

DIN ISO 10816-... Evaluation of vibrations of machines via measurements on non-rotating parts... (several parts)

DIN ISO 8821 „Mechanical vibrations, agreement about the feather-key type by balancing of shafts and composite parts“

DIN ISO 1940-... Requirements for the balancing quality of rigid rotors... (several parts)

DIN ISO 7919-… Measurement and evaluation of shaft vibrations

For explosion-proof machines the basic safety requirements of the directive 94/9/EC (ATEX) are guaranteed due to the standard design.

Standards for electrical equipment in gas explosive areas:

DIN EN 60079-0 General requirements

DIN EN 60079-2 Equipment protection via pressurisation „p“

DIN EN 60079-7 Equipment protection via increased safety „e“

DIN EN 60079-15 Construction, inspection and marking of electrical equipment of the type of ignition protection „n“

The delivery is possible on request according to other standards, as for example, the coordinated IEC standards or according to the special regulations of the industry, for example, Shell specification.

4. Compressor motors

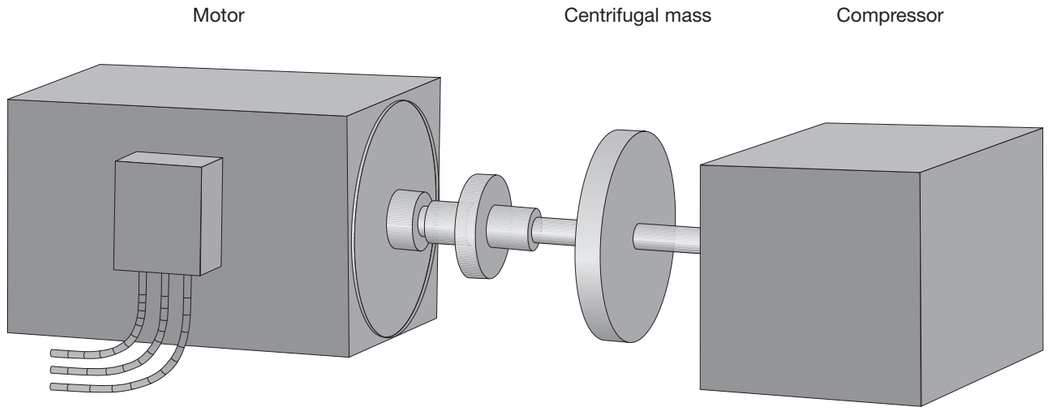
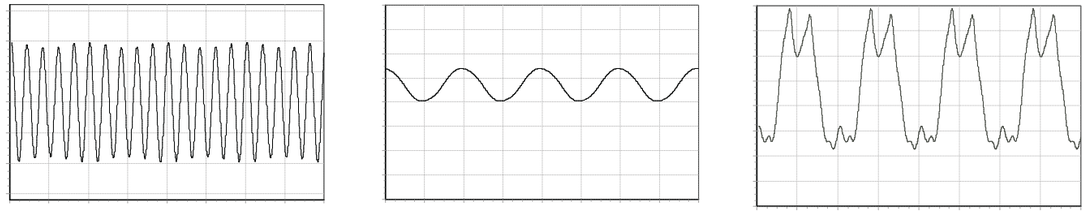


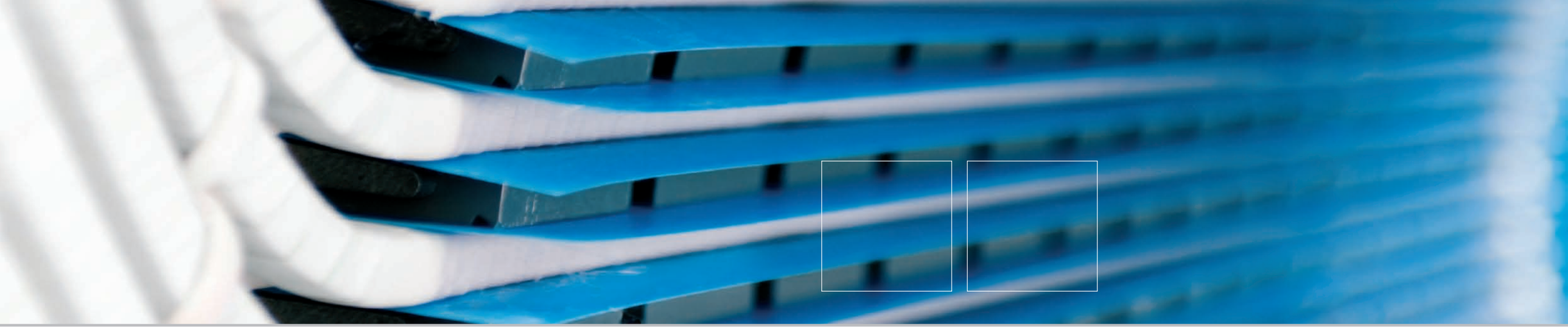
Chart 1



Motor stator current | Shaft torque | Compressor torque

Standardised current and torque curves from the dynamic evaluation of the shafting

www.vem-group.com



4.1 Design principles

Motors for the drive of compressors are classified in 2 areas.

The 1st area includes the high-speed drives with relatively consistent load torque. The motors are designed for S1 operation and for the start on the converter or for the direct starting on the mains.

The 2nd area concerns the low-speed motors for the drive of piston compressors. Characteristic of a piston compressor is that during every rotation the torque changes strongly due to the crank drive and due to the pressures on the piston area, which rise at each piston stroke according to the pressure – volume diagram (drawing 2).

A piston force Fp, the rod force Fs, the tangential force Ft and the torque on the motor shaft result from the pressure course p according to the following relations (Chart 3).

Principle of power transmission from motor to compressor piston

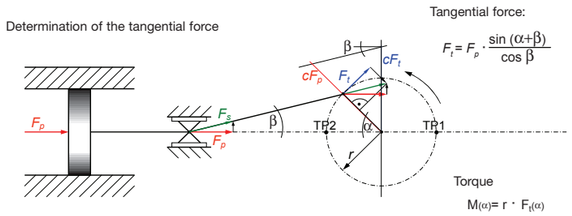


Chart 3

Pressure-Volume diagramm (indicator-diagramm)

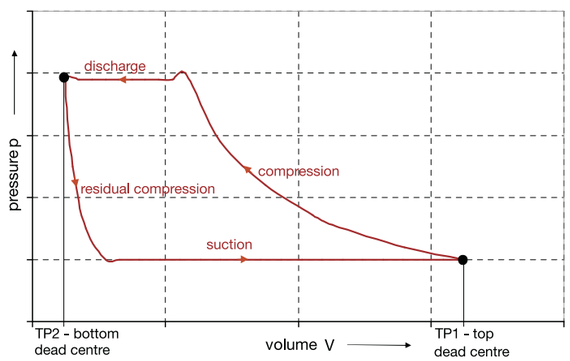


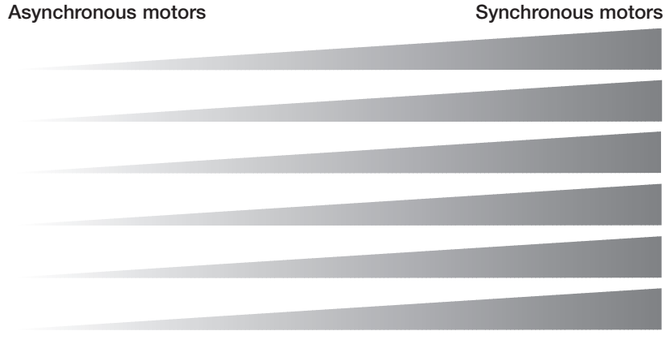
Chart 2

Due to the intensely changeable torque of the compressors, oscillations occur in the current and power consumption of the motor (Chart 1), which must be – to the greatest possible extent – suppressed by the increased torque of inertia and applicable measures in the motors or by the converters if applied.

If RPM-regulated asynchronous motors are used, a special attention should be paid to their own frequency, because they are often close to the frequencies of the alternating torques of the piston compressors. In these cases a dynamic calculation of the whole drive chain is always conducted by VEM Sachsenwerk.

Asynchronous and synchronous motors are used depending on requirements for the drive. A selection of the drive type should take place considering the following criteria.

Selection criteria



- Purchase costs
- Maintenance requirements
- Performance factor
- Efficiency
- tability on changing mains voltage
- Prevention of the synchronism at parallel running units

This organisation is the result of the fact that the application of synchronous motors is reasonable with very high performances / moments – in spite of the high purchase costs.

4.2 Voltage and frequency

In the basic design the motors are dimensioned for the rated voltage of 6 kV and the rated frequency of 50 Hz.

Variations in voltage and frequency during the operation are possible in accordance with specifications in the DW EN 60034-1 (VDE 0530 parts1) - IEC 60034-1.

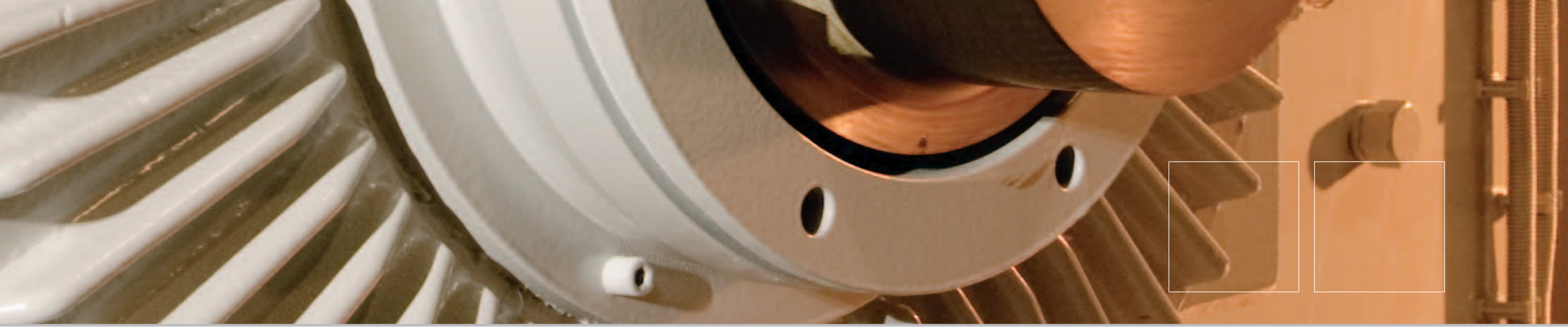
For similar designs motors show a higher rated power for a voltage range of ≤ 3.3 kV, and they show lower rated powers for a voltage range of > 6.6 kV.

4.3 Rated power and heating

The rated powers specified in the product range overview apply to the continuous operation (S1) with rated frequency, rated voltage, installation height of ≤ 1,000 m above sea level and the inlet temperature of cooling air of max. 40 °C or inlet temperature of cooling water of 27 °C. The maximum winding temperatures comply with the insulation material class B according to DIN EN 60 034-1, measured according to the resistance process.

Motors with the maximum heating according to the insulation material of class F are available.

www.vem-group.com



4.4 Direction of rotation

Basically the motors with self ventilation can be operated only in the arranged direction of rotation. If two directions of rotation are required, special ventilators can be applied. Ventilators for two directions of rotation cause higher friction losses and, therefore, worse degree of efficiency.

Motors with external ventilation units can be operated in both directions of rotation.

4.5 Overload capacity

The synchronous breakdown torque is at least 1.35 up to 1.5-fold of the rated torque by salient-pole and non-salient pole motors.
Asynchronous motors are equipped at least with 1.6-fold of the rated torque.
These values may be adjusted depending on the drive function.

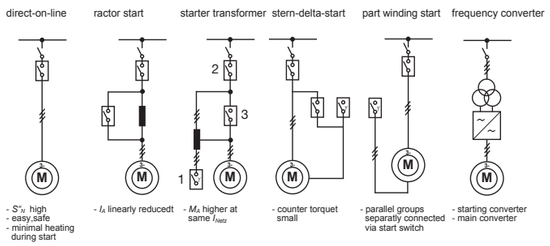
4.6 Start

The motors are generally designed for direct start. A reduced starting current is basically possible to be realised by means of:

- reduction of the stator voltage with an autotransformer or a coil
- tarting with the help of a frequency converter

At any rate the parameters of the working unit are to be specified for evaluation of the starting relations, such as

- Counter-torque curve (idle running until rated torque)
- Mass moment of inertia
- Maximum allowable voltage drop in the mains during the starting phase and short-circuit power
- Number of starts in immediate succession



Starting process – Frequency converter
Advantages of starting with a starting converter (synchronous and asynchronous motors):

- Starting with nominal torque at nominal current via the whole rpm-range and starting with reduced moment and thus with a power-reduced converter

Additional advantages during operation at the frequency converter:

- Adjusting the flow rate to the technology
- Stable bridging of short power failures and therefore pre vention of dangerous opposition connections
- Asynchronous motors: reduction of the current oscillations and therefore of the voltage oscillations on weak grids via „oscillation damping“ (adjustment of field rotation speed to the rotor speed) due to special control of the converter

4.7 Bearings

The type of applied bearing complies with the shaft size and the operating conditions. Motors with shaft ends larger than approx. 250 mm or with a speed above 1800 min^{-1} are usually equipped with sliding bearing.

The N-side bearing positions are insulated arranged for prevention of shaft currents. In some converter feeds an insulation of both bearing positions is required. In this case the motor is equipped with earth brushes.

4.7.1 Anti-friction bearings

The motors are equipped with standard anti-friction bearings. Smaller motors are equipped with groove ball bearings. For larger scale motors they are also used in combination with cylinder roller bearing. When axial forces emerge, special bearings with pre-stressed angular ball bearings are applied.

The fixed bearing is usally arranged on the D side. The sealing of the bearing inside the motor and outside it takes place via wearfree gap seals.

The anti-friction bearings are designed for a service life of at least 30,000 hours.

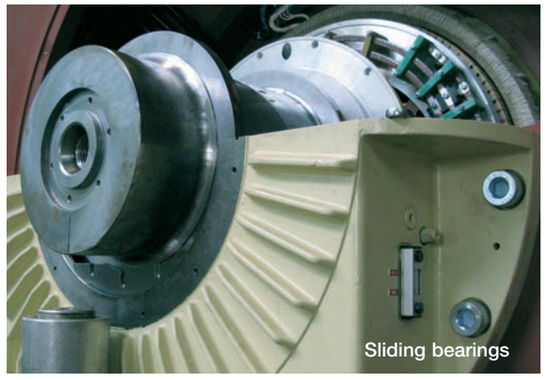
All anti-friction bearings are lubricated with lithium base grease, consistency class 3. The bearing components are equipped with an automatic grease feed regulation. This guarantees the optimal lubrication state after the re-lubrication.

4.7.2 Sliding bearings

Depending on the type of the motor sliding bearings are used as a flange bearing or a vertical bearing. The bearings consist of a split housing, a split bearing shell as well as split lubricating and sealing rings. Thus bearing revisions as well as application of sealing rings without disassembly of adjacent motor components or couplings are possible.

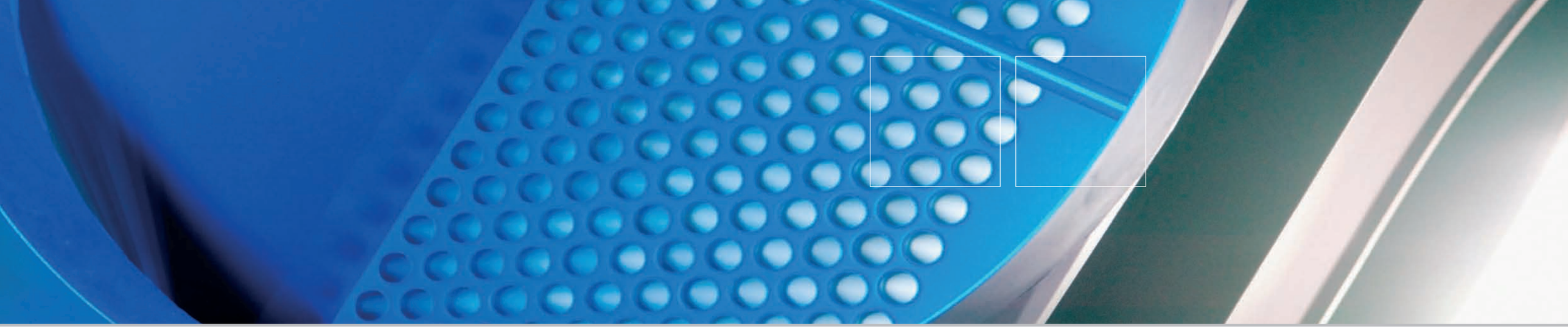
The sliding bearings are standardly designed as movable bearing, that is the rotor is guided via limited end-float coupling by the support bearing of the working unit. Nevertheless, a fixed bearing can be used, when no axial forces of the worknig unit or of the coupling are introduced to the motor shaft. Specific bearing shells are used when the accomodation of axial forces is required.

The cooling of the sliding bearing takes place particularly by means of heat emission via the surface of a bearing housing. If the operating conditions do not permit this, the bearings can be cooled by means of flushing oil or intergrated water cooler. A hydrostatic lifting of the rotor is used at lower speeds or larger rotor masses.


Sliding bearings

The lubrication takes place with standard lubricants, whose viscosity class is determined by means of the operational data of the sliding bearing. If deviant oils are used, we require to consult VEM Sachsenwerk.

www.vem-group.com



4.8 Cooling

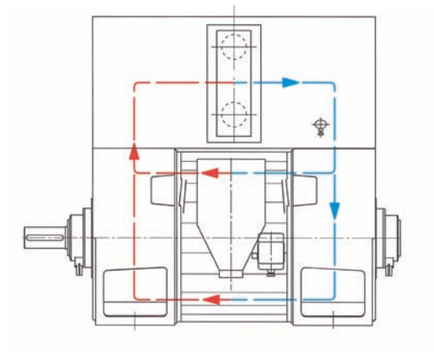
The cooling inside the motor takes place with air. This will be charged via fan wheels mounted on the shaft (self-cooling) or via additionally mounted ventilators with motor (external ventilator) axially or radially via the rotor and stator. Thereby it absorbs the lost heat from the lamination and the windings.

The selection of the cooling process taks place according to the project of the entire plant and is considerably defined via the necessary protection class and the available media.

The most common cooling methods are:

IC 81W / IC 86W

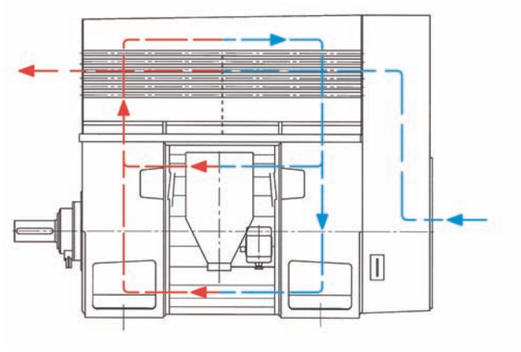
Motor with the internal closed cooling circuit and the mounted air-water heat exchanger (IP54/IP55)



The cooling air inside the motor is moved in a closed circuit and gives off its heat to the cooling water via an air-water heat exchanger. The used material of the heat exchanger complies with the quality of the cooling water.

IC 611 / IC 616 / IC 661 / IC 666

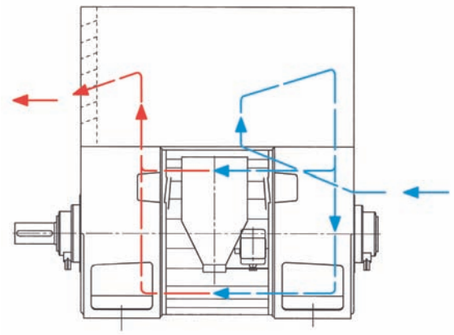
Motor with the internal closed cooling circuit and the mounted air-air heat exchanger (IP54/IP55)



The cooling air inside the motor is moved in a closed circuit and gives off its heat to the ambient air via an air-air heat exchanger. The ambient air is charged via a fan wheel on the N-side shaft end (self-cooling) or via the additionally mounted ventilator with motor (external ventilator) via the cooling pipes. The cooling pipes are made of aluminium.

IC 01 / IC06

Motor with free and open cooling circuit (IP23)



The cooling air is taken from the environment, flows through the inside of the motor and is released to the environment again. The applicable louvers are used to comply with the degree of protection.

Air-water heat exchanger

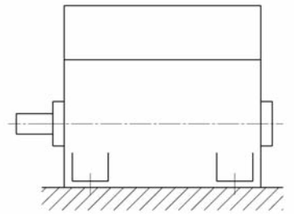
4.9 Types of design

The design of the motors is selected so that they are optimally adjusted to the constructive conditions of the compressor.

The most common types of design are:

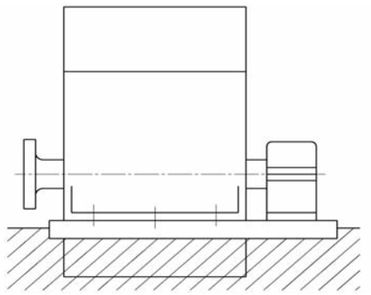
• **IM 1001 (IM B3)**

Motor with two plug-in type bearings, standard feet, a cylindrical shaft end



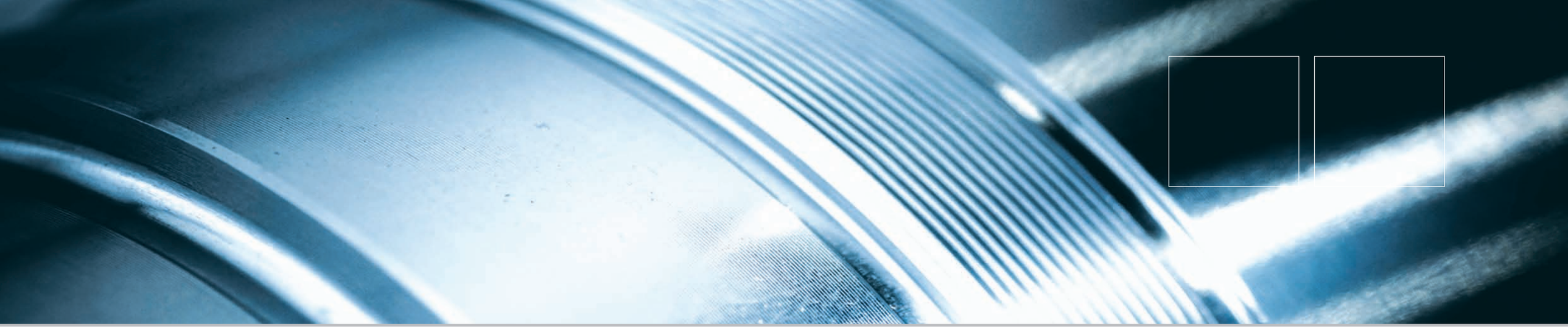
• **IM 7115**

Motor with a vertical bearing, base plate and lifted feet, a flange shaft end



For this type of design a foundation pit is required. The fixed bearing for the shafting is located in the compressor. The compressor bearing on the motor side must carry a part of the rotor mass.

www.vem-group.com



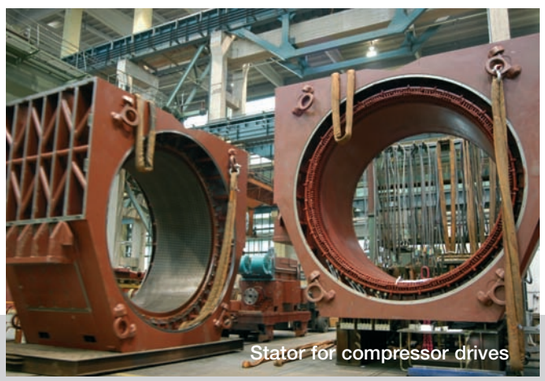
5.1 Stator
The stator housing is a weld construction made of bulkheads and partition walls with supporting ribs, beams and shell plates.
The lamination consists of insulated sheet blanks of dynamo machines or of sheet metal segments of dynamo machines, or of overlapped laminated sheet metal segments of dynamo machines and is axially clamped via end plates with moulding bolts.
For smaller and medium motors with a non-split stator the wound and impregnated lamination is shrunk in the housing, for large scale motors the sheet metal segments of dynamo machines are laminated in the parts of housing on the guide beads, tensed and finally wound with impregnated bars.

The three-phase stator winding is located in the open slots of the lamination. Depending on the efficiency level it is designed as winding of a two-layer preformed coil or of a two-layer Roebel bar.
The preformed coil winding consists of a flat copper wire insulated with film mica. For the conductor of the Roebel bar winding, cabled in the slot part, flat copper wires with the lacquer glass-fibre insulation are used, reinforced as a conductor bundle with mica prepreg.

The main insulation of the coils and bars consists of mica glass fabric tapes with low content of a binding agent. To prevent corona discharges, a corona-protection film with a low resistance is applied in the slot part and a corona-protection film with a high resistance is applied on the slot output.

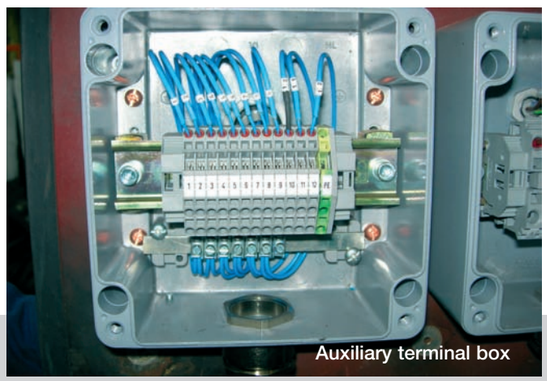
The complete insulated conductor cores are set in the slots by means of slot locks of glass fabric epoxy resin.
The end windings are safely supported against the mechanical loads, emerged from switching operations, by means of bindings, spacers and supporting rings.
The switching connections are brazed by the preformed coil winding, the bar connections at the Roebel bar windings take place via WIG gas-shielded arc welding.
The stators with the inserted preformed coils, with a diameter of up to 4,300 mm, are completely impregnated according to the insulation system VEMoDUR-VPI-155.

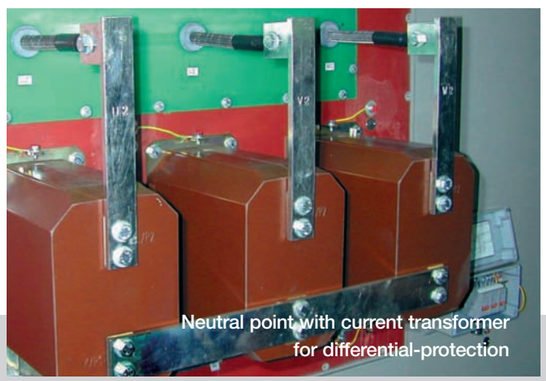
5.2 erminal boxes
All terminal boxes are designed as a basic version with protection class IP54/IP55.


Stator for compressor drives

5.2.1 Connection – stator
The cable terminal box is located on the side panel of the stator housing.
The box is designed as two-parts weld construction. The bottom part is screwed on a plate of the housing. A rated break point is in the bottom part for pressure release in case of short circuit. The bores in the bottom part accommodate short-circuit proof cast resin insulators. In case of smaller currents duct bolts are located in the cast resin insulators, in which the cables are soldered in for the stator winding. In case of larger currents the cast resin insulators carry bus bars, to which the cables are screwed for the stator winding. In both cases the network connection takes place by means of the fixed cable lugs.
The cable outlet takes place downwards. The applied cable screw connections are selected suitably for the customer-supplied cable. By request the box can be also delivered with an undrilled end plate, onto which the cables for the stator winding are screwed. In both cases, the connection to the mains is realised by means of screwed-on cable lugs.

5.2.2 Connection – other equipment
Other terminal boxes for connection of excitation (only synchronous motors), standstill heating, fan motors, resistance thermometers and other monitoring devices are mounted on the stator. They consist of a low corrosive aluminium cast alloy. The cable outlet takes place via cable screw connections.


Auxiliary terminal box


Neutral point with current transformer for differential-protection

5.3 Squirrel-cage rotor for asynchronous motors

The short-circuit rotor consists of a forged shaft with the shrink lamination. The lamination is set of insulated sheet blanks of dynamo machines.
For motors with larger stator diameter the rib shafts or shafts with rotor bodies are used. They accommodate overlapped laminated sheet metal segments of dynamo machines.
The lamination is axially clamped via end plates with moulding bolts.

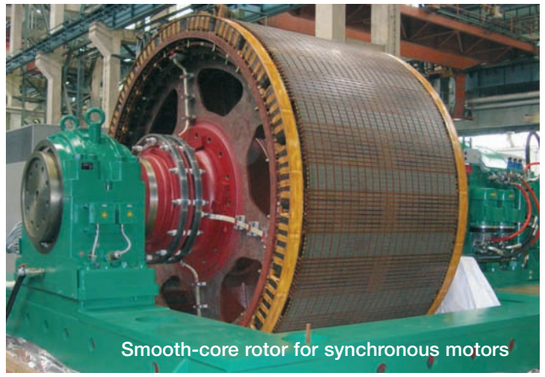
The short-circuit bars of copper or copper alloy are located in the slots of the dynamo sheets. They are inductively braced axially with short-circuit discs.
The special design of the short-circuit disc and of the rotor bars guarantees a high-quality soldering and a radial fuse of the short-circuit bars in case of the vertical soldering. Only after the soldering the outer contour of the shot-circuit discs is machined in order to reach an optimal state of the active force.
Closely tolerated slot dimensions and rotor bars as well as an additional impregnation guarantee a secure fit of the rotor bars under all operating conditions.
For high-speed motors special types of construction with additional shrink rings are selected on the connection between a short-circuit bar and a short-circuit disc.

5.4 Rotor for synchronous motors

The construction of the rotor complies with the mechanical loads and the starting conditions.
The synchronous motors are delivered with the exciter according to the standard.
This version is brushless, maintenance-free and is also applicable when the motor is operated in an explosive atmosphere. Alternatively the excitation can also take place via slip rings and brushes.

5.4.1 Smooth-core rotor

The smooth-core rotor consists of a forged shaft with the shrink lamination. The lamination is set of insulated sheet blanks of dynamo machines.
For motors with larger rotor diameter the rib shafts or shafts with rotor bodies are used. They accommodate overlapped laminated sheet metal segments of dynamo machines.
The lamination is axially tensed via end plates with moulding bolts.



Smooth-core rotor for synchronous motors

In the slots of the dynamo sheets the excitation winding is inserted and is fixed with slot locks. The enamel-insulated profile wires with glass fibre are used for the excitation winding. The rotor is completely impragnated according to the insulation system VEMoDUR-VPI-155.
The slots that accommodate the damping bars are located, consistently arranged on the outer perimeter of the rotor lamination.
The damping bars are hard-soldered with short-circuit discs on the ends and at the same time they form the squirrel cage for direct starting.
Specially designed starting cage is used for starts with relatively high mass moments of inertia or with high counter moments.

5.4.2 Salient-pole rotor with laminated poles

A cast rotor body is mounted on a forged shaft or flanged on a forged shaft.
The poles are laminated of sheets, pressed with end plates and screwed with bolts. The poles are wound directly with insulated flat copper wire and impregnated according to the insulation system VEMoDUR-VPI-155.
Additionally slots that accommodate the damping bars are located in the pole caps.
The complete poles are screwed on the rotor bodies or fixed with T-head slots and wedges at high tangential forces.
The coils of the poles are interconnected and form the excitation winding.
The ends of the damping bars are short-circuited with damping segments.

Salient-pole rotor

5.4.3 Salient-pole rotor with solid poles

The shaft with pole cores consists of an all over machined forging. Exciter coils are insulatedly attached on the pole cores. They are casted with resin for better heat emission and mechanical stability. Forged pole caps are mounted on the pole cores. The coils of the poles are interconnected and form the excitation winding.
For this version no special damping winding is required.

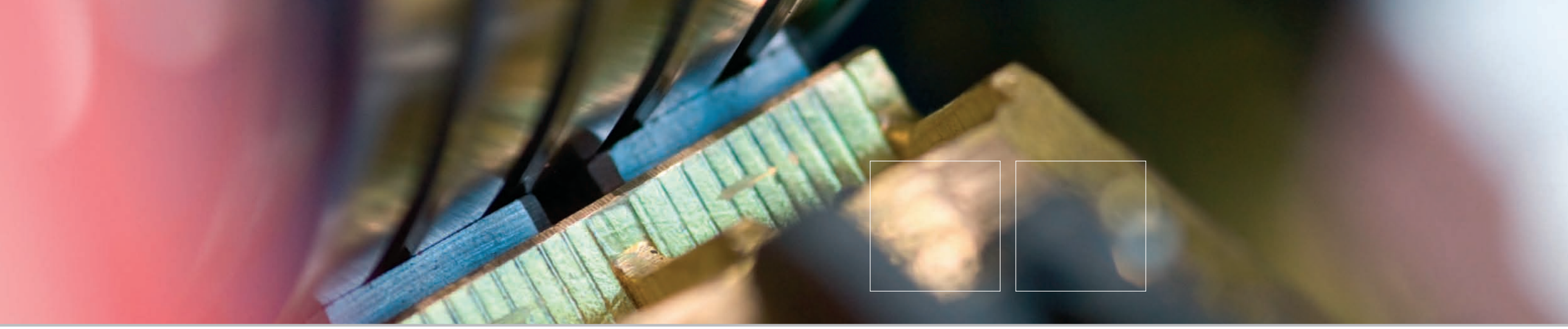
5.5 Excitation

5.5.1 Exciter cabinet

The exciter unit is mainly designed as a control cabinet, for static devices as several control cabinets.
In case of simple devices for small powers other constructions such as engine mounting, wall mounting and mounting plate, may also be delivered. The characteristics of the cabinet are adjusted according to the case of application.
The control cabinet of sheet steel contains the complete exciter regulation and control.
If a local operating option or indication is required, the corresponding equipment is mounted on the door of the control cabinet. There is also the possibility to mount the operating elements on the pivoting frame and to attach a viewing door.

The control cabinets are supplied with bottom plates according to the standard and the cables are sealed by means of the foam plastic. On request the cables can be also inserted via high-strength cable glands.

www.vem-group.com



5.5.2 Function of the excitation system

The excitation system contains the control system and the regulation of the synchronous motors.
The control system is adjusted to the corresponding plant. The differences are particularly in the starting of the motor. For example, the switches of the Korndorfer connection or a soft starter can be operated in this manner.
In case of synchronisation of the motor static and brushless excitation systems are to be distinguished.
Static excitation systems have a direct access to the excitation winding of the machine, synchronise the machine according to the starting conditions and provide for the overload protection of the magnet wheel.
For brushless excitation systems these functions are in the rotating electronic systems. The construction types for easy and heavy starting are available.
The connection of the excitation device takes place according to the applied rotating electronic systems.

The control of the excitation device is active after the mains hold.

The control of a synchronous motor via its excitation takes place always under consideration of the drive stability and the E-plants as well as depending on the mains. Both factors are not oppositional but nevertheless a balanced planning of the entire plant should be taken as a basis.
Mostly a blind power control is applied in order to work with a subordinate exciting current control, wherefrom advantageous adjusting times result. Alternatively the cos φ-control (cosine Phi-control) may also be applied as a modified form of the blind power control.

Another additional controller can be superposed by the blind power controller, for example, in order to maintain the blind power of a sub-network. This is of course possible only in line with the operating range of the synchronous motor.

A range of limiting controllers primarily prevents the loss of stability of the motor. The angle stop of the magnet wheel is based on the detection of real and blind power.

The exciting current control serves for purposes of revision and manual operation.
Thereby, the internal rated value is adjusted as usually via HIGH/LOW signals.
The actual value is measured automatically in the excitation device. Digital devices are applied as a controller. .

Basic functions:

- Blind power control
- Exciting current control
- Digital director
- Exciting current limiting
- Limitation of under and over-excitation
- Angle stop of the magnet wheel
- Blind power limitation
- Failure detection for rotating diodes (for brushless systems)

Via the control system other functions can be realised such as:

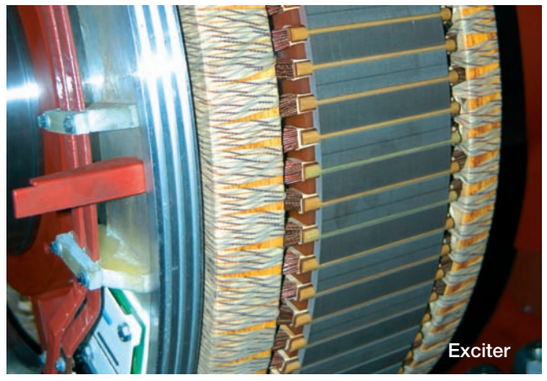
- Detection of asynchronous running
- Monitoring of frequency of starting
- Blocking monitoring
- Monitoring of motor startup

On request a motor protection device can also be integrated in the excitation device. All standard protective functions are available then.

The brushless version is maintenance-free. The rotating brushless exciter unit (exciter, rectifier, starting thyristor, protective circuit and starting resistance) is arranged either inside the machine or outside the machine.

The exciter is designed – depending on the required mode of operation of the motor – as:

- 3-phase integrated exciter with DC-supply on the stator side and
- 3-phase exciter with three-phase supply on the stator side.



Exciter

The rotor of the exciter supplies the excitation winding of the motor via rotating rectifier module in three-phase bridge circuit with excitation power.

5.5.3 Excitation via exciter

The exciter is located inside the machine according to the standard, between rotor lamination and N-side bearing.

The exciter consists of:

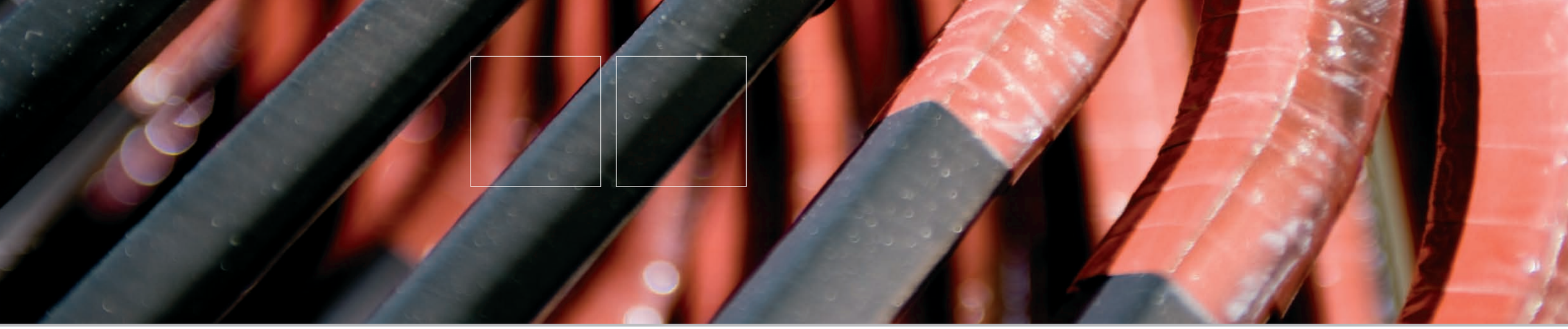
- Stator with DC or three-phase supply, depending on the required mode of operation of the motor
- Rotor with three-phase winding
- Rectifier bridge with protective circuit, with starting resistances if required

The excitation power is fed in the stator of the exciter.
In the rotor winding of the exciter a voltage is induced that is conducted via the rectifier bridge of the exciter of the rotor of the synchronous motor.

5.5.4 Excitation via slip rings

The brush carriers with brush holders, which accommodate carbon brushes, are located inside the motor, on the N-side end shield or on a special support star.
The excitation power is supplied in the brush holder.
The slip rings are located between rotor lamination and N-side bearing.
The slip rings are made of stainless steel. They are connected to the excitation winding of the rotor and supply the excitation power.

www.vem-group.com



6. Options

- Neutral point box for stator winding on the opposite side of the cable termination box
- Mounting of turning devices for maintenance of the compressor
- Mounting of centrifugal masses
- Assembly of standstill heating
- Auxiliary terminal boxes in stainless steel
- Monitoring of shaft vibrations (for sliding bearing motors)
- SPM (Shock Pulse Method for anti-friction bearing motors)
- Air-water heat exchanger in double pipe version
- Flow control device in the hydraulic system
- Detectors for leakage water of the air-water heat exchanger
- Increased service life of the bearing for anti-friction bearings (up to 100,000 hours)
- Oil systems for sliding bearings
- Sliding bearings with hydrostatic rotor lifting
- Throttle screws for adjustment of the oil flow rate and flow rate indicator or controller for sliding bearings with flood lubrication
- Speed sensor
- Fastening material, anchor bolt, shim plate, …

7. Explosion-proof motors

The guidelines of the directives 94/9/EC (ATEX 95) and 99/92/EC (ATEX 137) apply to the assembly of motors in explosive areas.
Thereby the explosive areas are divided into zones and the equipment that is also the electrical motors, are divided into equipment groups and categories. By means of implementation of the series of standards IEC 60079 for gas explosive areas and the series of standards IEC 61241 for areas with combustible dust the guidelines are complied with the directives.

For gas explosive areas of the zone 1 the motors of the equipment group II category 2 are provided:

- Pressurisation „p“
  (according to DIN EN 60079-2, IEC 60079-2)
- Increased safety „e“
  (according to DIN EN 60079-7, IEC 60079-7)

Synchronous motor for frequency converter operation

For gas explosive areas of the zone 2 the motors of the equipment group II category 3 are provided:

- Type of ignition protection „n“ non-sparking in the normal operation (according to DIN EN 60079-15, IEC 60079-15)

For explosion-proof motors in the type of ignition protection „e“ according to IEC 60079-7 and „n“ according to IEC 60079-15 a risk evaluation for possible ignition hazards has to be carried out together with the customer during the contract preparation and the measures for reducing risks are to be agreed contractually if applicable. One of the measures for reducing risks for high-voltage machines is the type test for the insulation system of the stator windings under explosive atmosphere. The corresponding certificates of the PTB Braunschweig (National Metrology Institute) are available for the insulation system Sachsenwerk VEMoDUR-VPI-155 as a notified body. Without restrictions in the gas type a variant for rated voltages of up to U_N = 6.6 kV and another variant for rated voltages of up to U_N = 11 kV are provided.

8. Universal insulation system VEMoDUR

The operational reliability of electrical machines is defined dependent on the quality of its winding insulation.
Typical for the insulation technology there have always been technical solutions in the Sachsenwerk that comply with the international standards in their quality parameters and therefore guarantee the users products with high reliability and long service life.

For high-voltage machines the VPI technology (Vacuum-Pressure-Impregnation) is applied. The universal insulation system VEMoDUR-VPI-I 55 was developed in the Sachsenwerk and is registered as trademark. In addition the term „VEMoDUR“ as a company-specific system name „VPI“ identifies the method of Vacuum-Pressure-Impregnation and the figures „155“ as symbol (marking) identifies the thermal class of the insulation system.

VEMoDUR

In this system the following basic components are included for the stator windings:

Components	Insulating material
Winding insulation	Film mica tapes
Main insulation (slot ends and end windings)	Mica fibre glass types (containing catalyst, with low content of binding agent)
Impregnant	Epoxy resin

www.vem-group.com

The components are optimally compatible with one another. The thermal class F was certified due to many years of operational experience and functional evaluation according to DIN EN 60034-18-31 (VDE 0530 Part 18-31) – IEC 60034-18-31.

In order to guarantee the quality of the insulation system all components according to DIN ISO 9001 were subject to an incoming goods inspection.

During the winding production the electrical characteristics were tested in line with the internal quality control with in-process and final inspections.

The process of impregnation is adjusted to the corresponding insulation construction and is based on the systematic process analyses as well as on the successful application in practice for many years.

During the process of impregnation the insulation is subject to a regular control system whereas all characteristic values are checked and documented.

Impregnation-plant VEMoDUR

The hardening of the insulation takes place in a rotating manner.

The vacuum pressure impregnation method guarantees a high mechanical strength (rigidity of end winding) and excellent electric strength. This particularly applies to the high breakdown voltages. Rated surge voltages according to DIN EN 60034-15 (VDE 0530 Part 15) -IEC 60034-15 are guaranteed for all machines with high safety (see an extract from the table).

Insulation level of rotating electrical machines with stator preformed coil windings according to DIN EN 60034-15 (VDE 0530 Part 15) - IEC 60034-15 (Extract).

Rated voltage U_N in kV	Rated sure voltage (peak value) in kV shaft 1,2/50 ($4U_N$ + 5 kV)	Test voltage of power frequency (rms-value) in kV ($2U_N$ + 1 kV)
6 6,6	29 31	13 14,2
10 11	45 49	21 23
13,8 15	60 65	28,6 31

On customer's request VEM is also able to deliver special models with increased rated surge voltage.

The insulation system is characterised by a high climate resistance, i.e. the winding is resistant to humid and aggressive atmosphere.

The VPI insulation system is considered as standard version.

For larger scale machines the technically equivalent resin-rich insulation system is applied. In these machines for the basic insulation and the insulation of end windings highly resinous mica glass fabric insulating tapes are loosed and set under pressure and heat in the slot part.

In line with the internal quality test according to DIN VDE the electrical in-process and final inspections in the insulating strength as well as surge voltage and partial discharge inspections on customer's request. This guarantees a market-driven and competitive quality.

The insulation system VEMoDUR is also suitable for machines with a type of ignition protection – equipment protection by means of increased safety "e" - Ex e according to DIN EN 60079-7 / IEC 60079-7.

9. Inspections

An effective quality assurance and management system according to DIN EN ISO 9001:2008 guarantees the optimal performance and quality of the motors.
Every motor is subject to an internal routine check test. The results if the tests are documented in an inspection certificate. This is a part of the delivery documentation..

Routine check tests

- Visual inspection (marking, completeness, constructive condition, assembly quality etc.)
- Air-gap measurement (for possible construction type)
- Insulation resistances of windings, temperature sensor, standstill heating systems, bearings (Inspection takes place during the assembly)
- DC resistances of windings, temperature sensor, standstill heating systems
- Measurement of magnet wheel impedance
- Adjustment of the magnetic centre for sliding bearings
- Idle running curve for determination of the iron and friction losses, calculated inspection of efficiency if required
- Inspection of the rotating direction
- Inspection of the voltage symmetry
- Inspection of the winding
- Measurement of vibration severity
- Short-circuit curve and measurement of loss (the generator's method)
- Determination of the SPM level (Shock Pulse Method) for the corresponding equipment
- Inspection of current overload
- Overspeed test
- Winding test (high-voltage test)
- Functional capability of the accessories

www.vem-group.com

Type tests
On purchaser's request further inspections may be carried out in a scope of the type test. For this matter the following inspections will be taken, additionally to the routine check test:

- Registration of the idle running curve and of loss measurement
- Noise measurement during idle running
- Shaft voltage measurement for machines with insulated bearings (for possible construction type)
- Distortion level of the voltage curve
- Measurement of the THF factor
- Reactances and time constants – detection of the residual voltage process
- Short-circuit curve and measurement of loss (motor's method)
- Inspection of sudden short circuit
- Load curve
- Control characteristics
- Detection of the rated exciting current
- Efficiency determination
- Air volume measurement, losses of pressure
- Temperature-rise test with rated values or alternative tests
- Standstill heating
- Heating time constants, determination of the limit capacity
- Cooling time constant
- Discharge measurement, detection of the moment of inertia
- Run-up measurement, detection of the starting characte ristic
- Detection of the parameter of the synchronous machine
- Measurement of the SPM level
- Operating characteristics η=f (Pel), cos φ=f (Pel), Pmech=f (Pel), s=f (Pel), I=f (Pel)

These inspections require additional costs. The additional expenditures will be passed by VEM Sachsenwerk on the purchaser.

10. Documentation

Unless otherwise agreed, the „operation and maintenance manual" contains the following documents:

- Safety instructions
- EC declaration of assembly according to the machinery directive
- EC certificate of conformity for machines for application in explosive atmosphere (ATEX)
- Description / Technical specifications
- Dimensional drawing – motor
- Shaft drawing with details on the shafting measurement
- Dimensional drawing – cable connection
- Terminal connection diagrams
- Installation / Assembly
- Commissioning
- Operation
- Maintenance / Servicing
- Spare parts list
- Logbook
- Inspection sheets
- Additional operation manuals (options, external suppliers).

The documentation is provided in duplicate with the delivery of the product.
The documentation is available in the following languages: German, English, French, Russian and Spanish.

Additional costs will be charged by VEM for additional copies, an extended scope of documentation and translations in other languages.

11. Transportation, package and assembly

The type of package is determined on conclusion of the contract according to the transportation and storage conditions, which are mentioned with an order, as well as considering the design of the machines.
VEM Sachsenwerk offers all kind of special packages and carries out worldwide delivery and installation of the motors.

The transportation of the machine takes place depending on the size and according to the contractual agreements either completely mounted or demounted.
VEM Sachsenwerk recommends you to let our personnel carry out the required assembly and commissioning services. If the customer would like to carry out the assembly and commissioning by himself or by a third party, the right execution of these services must be verified in the chapter 9 (inspection sheet, logbook) of the operation and maintenance manual of VEM machines or in any other way. A liability and warranty by VEM Sachsenwerk are excluded, when this verification cannot be provided.
The operation and maintenance manual is delivered with the machine.
According to the corresponding contractual agreement the documentation can also be delivered separately to the purchaser and user.

www.vem-group.com

12. General instructions

Unless otherwise explicitly requested or provided, the machine/s is/are designed as follows:

- The production takes place with the insulation system VEMoDUR.
- The coating takes place according to the standard of Sachsenwerk SW-N 170-004, which is based on the DIN EN ISO 12944... - ISO 12944... and on the applicable standards.
- The rotating direction of the machine is to the right if looking on the drive end (DE). The terminal box is arranged on the right.
- The cooler is located on the machine and the water connection is arranged on the left, if looking on the drive end (DE).
- The water cooler up to connection flange without water-side monitoring.
- Without a cable gland
- PT 100 for winding and bearing in 2-conductor circuit without a circuit breaker, from a connection of the terminal box in 2-, 3- and 4- wire configuration.
- Mechanical vibrations comply with the limiting values, specified in the EN 60034-14 and are verified in the testing area.
- Monitoring of vibrations without an evaluation device.

13. References

Three-phase high-voltage asynchronous motors with squirrel-cage rotor

VALCEA / Romania	3,700 / 4,100 kW	2009, 2004
NLMK 3-7 Lipetzk / Russia	2,100 kW	2008
Fluxys Zelgate / Belgum	6,400 kW	2007
Norilsk / Russia	10,300 kW	2006
REA Cottam / U.K.	500 kW	2007, 2006
AHWAZ / Iran	5,600 / 7,800 kW	2005
Suez II / Alexfert / Egypt	750	2004
REVDA / Russia	3,500 / 4,200 kW	2004
Steel works Thyssen Duisburg / Germany	10,500 / 7,100 kW	2000, 1999

Three-phase high-voltage asynchronous motors with slip-ring rotor

Port Kembla / Australia	4,400 kW	2006
Degussa Worms / Germany	2,050 kW	2006
Jakhira / Libya	7,000 kW	1999

Three-phase high-voltage synchronous motors

MAPTAPUTH / Thailand	22,500 / 7,100 kW	2009
Bergwerk Skalisty Norilsk / Russia	8,000 kW	2009
Linde Linz LZ9 / Austria	14,000 kW	2007
LDPE Tasnee / Saudi Arabia	27,500 / 7,600 kW	2007
LDPE Bandar Imam / Iran	22,500 / 7,000 kW	2007
LDPE Marun / Iran	22,400 / 6.500 kW	2003
Kollsnes / Norway	18,500 kW	2003
Lesum / Germany	3,250 kW	2001, 1999
LDPE BASELL / France	23,500 / 5,600 kW	1999

www.vem-group.com