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Three-phase asynchronous motors with squirrel-cage and slipring rotor up to 500 kW
Rollertable motors up to 160 kW
Explosion-protected motors up to 630 kW
Crane motors and marine motors
Special motors with brake, forced ventilator, encoder
Compact drives up to 22 kw
Energy-saving motors
Built-in motors
Tree-phase asynchronous generators

High-voltage machines

High-voltage asynchronous motors up to 28 MW
High-voltage synchronous motors up to 35 MW
High-voltage synchronous generators up to 45 MVA
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Customer-made castings
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we get things moving

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Three-Phase Synchronous Motors

800 to 35,000 kW

Cover picture
Tree-phase synchronous motors

Page

Foreword

VEM is one of the leading European suppliers of electrical machines for industrial applications. Our range of three-phase high-voltage synchronous machines is primarily used in applications in the chemical and petrochemical industry, in steel and rolling mill technology, in shipbuilding, in the cement industry and in the manufacturing industry. With this range we can offer our customers a choice of high-performance drives with a global pedigree. In their various design applications and different protection classes and cooling types, the drives are suitable for use in piston compressors, milling drives, pumps, fans, blowers and transformers.

VEM can offer the right solution for any application with customer-specific and application-orientated machines. The are characterised by reliability, ease of maintenance, modular design, high utilization and low noise emissions. A solid design concept ensures the high level of adaptability required to be able to incorporate individual customer requirements.

Comprehensive know-how in the factory and constant further development in collaboration with institutes and universities guarantee high-quality customer-specific solution.

The main features include:

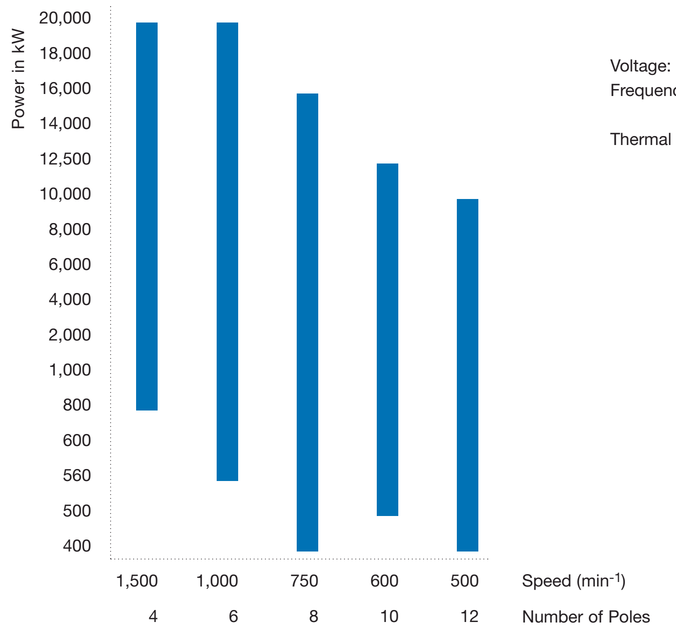
- Long service life of windings with high, reliable switching frequency thanks to the use of the universal VEMoDUR insulating system, wich is backed with decades' of experience.
- Inherent 20% thermal reserve built in tho the motors as standard.
- Splinter-proof design of terminal boxes.
- Good weight-to-performance ratio offers improved installation conditions.
- Modular motor design ensures that spare capacity can be built into the system both easily and cost-effectively.
- Minimal maintenance requirements, particularly on variants with brushless excitation.
- Electromagnetic optimisation delivers high degree of utilization.
- Excitation devices for motors without brushes ands for slipring motors supplied with automatic synchronisation and asynchronous running protection.

All motors are designed in a customer-specific manner to fulfil the special application criteria.
The catalogue contains general technical explanations. Individual requirements must be treated separately. The technical data for the basic series are also available on request from VEM.
We request that interested parties contact our factory sales department or VEM sales offices and VEM representatives.
Orders require our written confirmation.

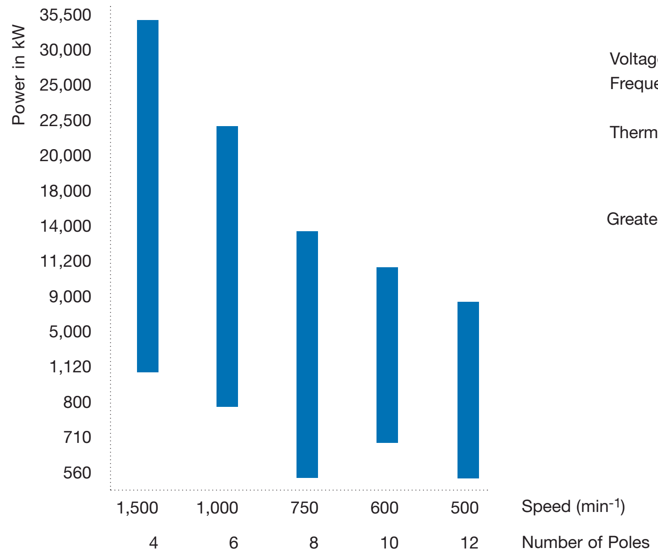
Note:
We make every effort to constantly improve our products. For this reason, versions, technical data and illustrations may be changed. They are not binding until confirmed in writing by the supplying factory.

1. Summary of supply

1.1 Synchronous motors with constant speed and brushless excitation



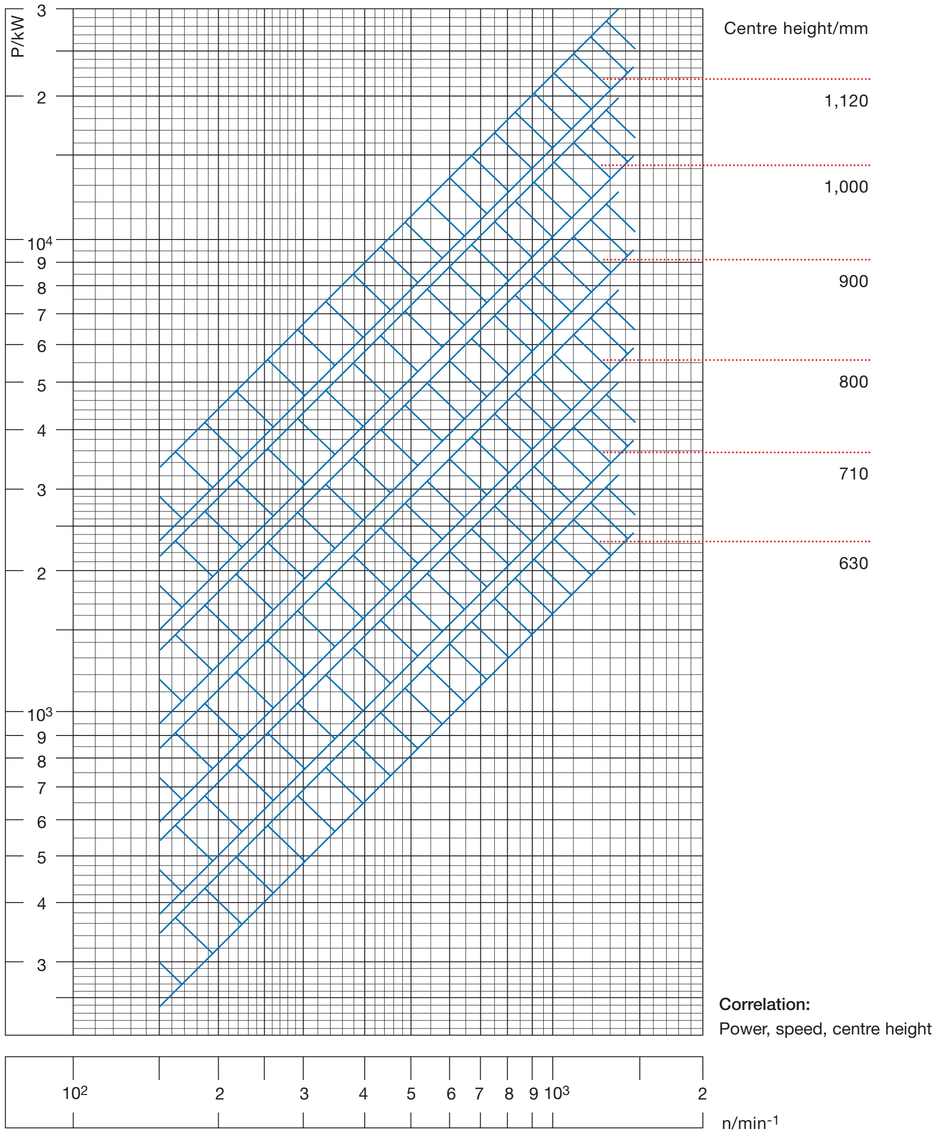
Voltage: 6 kV
Frequency: 50 Hz
Power factor: cos φ = 0.9
Thermal class: F / utilization B



Voltage: 10 kV
Frequency: 50 Hz
Power factor: cos φ = 0.9
Thermal class: F / utilization B

Greater numbers of poles available on request.

1.2 Synchronous motors with speed control



- Thermal class F / utilization B
- Rated voltage < 6 kV
- Air-to-water heat exchanger with forced ventilator
- xd“ = 11 – 16%
- Excitation: brushless/with brush

2. Type designation

The Sachsenwerk model designations consist of letters and numbers.

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

	D	M	M	V	X	2	1	0	6	4	8	W	D	
Position	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**

1 **Type of current**
E = Single-phase AC
D = Three-phase AC
M = Multiple-phase AC

2 **Machine type**
A AC current asynchronous generator
K AC current asynchronous squirrel cage rotor motor
B AC current asynchronous slip ring rotor motor with BAV
S AC current asynchronous slip ring rotor motor without BAV
G AC current synchronous generator with slip rings
R AC current synchronous generator without slip rings
M AC current synchronous motor with slip rings
T AC current synchronous motor without slip rings
C AC current commutator motor
U AC current single-housing converter

3 **Cooling type, protection class**
E Ventilated cooling / self-cooling without add-ons (IP00; IP10; IP20; IP21; IP22; IP23)
A Ventilated cooling / self-cooling with add-ons (IP23;
F Ventilated cooling / self-cooling pipe connection with internal fan (IP44; IP54; IP55)
L Draft ventilation / forced-air cooling supplemental ventilation unit or pipe connection (IP00; IP10; IP20; IP21; IP22; IP23; IP24)
B Draft ventilation / forced-air cooling pipe connection (IP44; IP54; IP55)
R Circulation cooling / self-cooling air-to-air cooler (IP44; IP54; IP55)
K Circulation cooling / self-cooling air-to-water cooler (IP44; IP54; IP55)
S Circulation cooling / forced-air cooling with air-to-air cooler with additional ventilation unit (IP44; IP54; IP55)
M Circulation cooling / forced-air cooling with air-to-water cooler with additional ventilation unit (IP44; IP54; IP55)
N Circulation cooling / self cooling or forced-air cooling with gas as refrigerant (except air); all protection ratings
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 fan (IP44; IP54; IP55)
W Surface cooling / forced-air cooling with water cooling jacket (IP54)
V Surface cooling / forced-air cooling with additional ventilation unit (IP54)

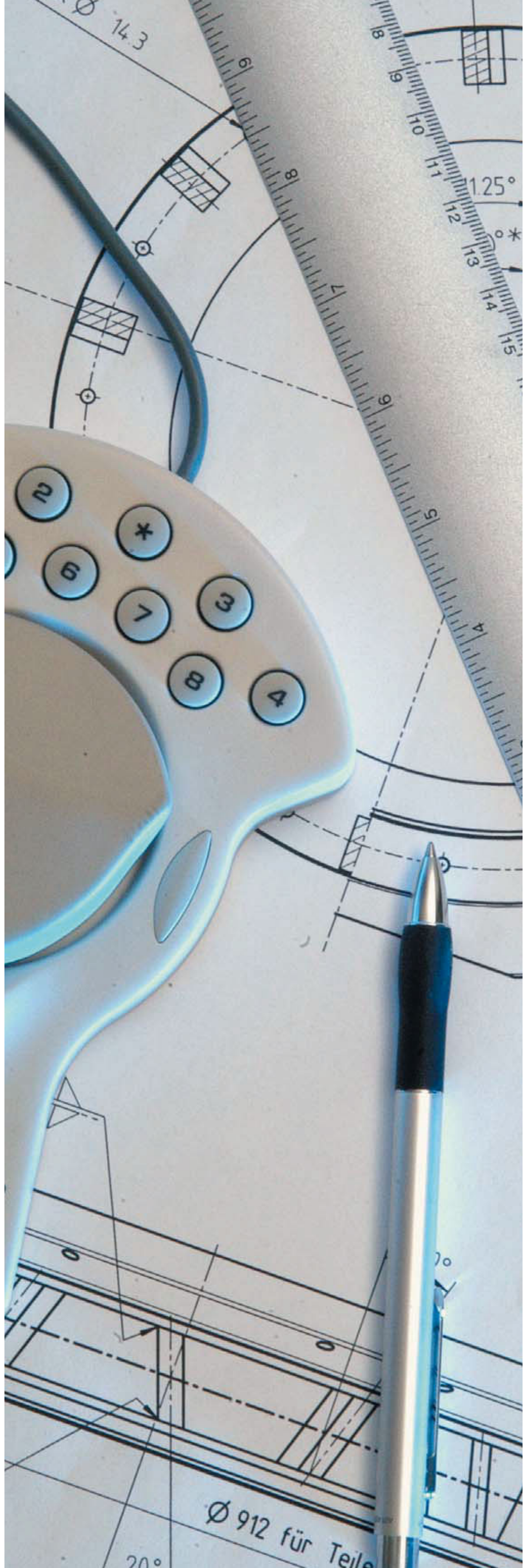
4 and 5 **Design type** (encoded)
Bearings, deviating voltage and frequency, Explosion protection, construction, high-load start, etc.

6 and 7 **Shaft centre height** (encoded)

8 and 9 **Stamping pack length** (encoded)

10 and 11 **Number of poles/speed**

12 to 14 **Additional letter for rework stage and special conditions**
Letter codes for special winding designs



3. Standards and regulations

The motors comply with the applicable DIN standards and the DIN VDE regulations. For the basic designs, these include, in particular, DIN EN 60034 (VDE 0530) and IEC 60034 with its parts:

Part 1 Dimensioning and operational behaviour
DIN EN 60034-1 (VDE 0530-1) - IEC 60034-1
Part 2 Methods for determining the loss of efficiency ...
DIN EN 60034-2 (VDE 0530-2) - IEC 60034-2
Part 4 Methods for determining key synchronous machine variables from tests
DIN EN 60034-4, VDE 0530-4, IEC 60034-4
Part 5 Classification of protection classes
DIN EN 60034-5 (VDE 0530-5) - IEC 60034-5
Part 6 Classification of cooling methods
DIN EN 60034-6 (VDE 0530-6) - IEC 60034-6
Part 7 Classification of design types
DIN EN 60034-7 (VDE 0530-7) - IEC 60034-7
Part 8 Connection designations and direction of rotation
DIN EN 60034-8 (VDE 0530-8) - IEC 60034-8
Part 9 Noise limits
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 Surge voltage ratings ...
DIN EN 60034-15 (VDE 0530-15) - IEC 60034-15
Part 16 Excitation systems 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-... several parts

as well as

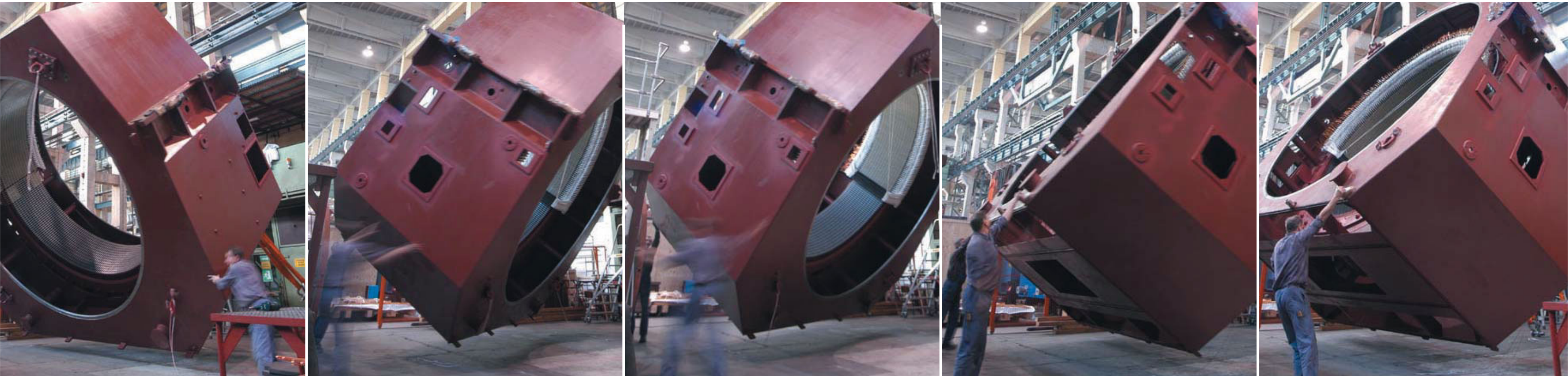
DIN ISO 10816-... - ISO 10816...	Evaluation of the vibrations of machines through measurements of non-rotating parts... (several parts)
DIN ISO 8821 - ISO 8821	Mechanical vibrations, agreement on the feather key type when balancing shafts and connecting parts
DIN ISO 1940-... - ISO 1940...	Requirements for the balancing quality of rigid rotors ... (several parts)
DIN ISO 7919-… - ISO 7919	Measurement and evaluation of mechanical vibrations

In the case of explosion-proof machines, the fundamental safety requirements are ensured by designs that meet the standards:

DIN EN 50014 (VDE 0170/0171 part 1),
DIN EN 60079-0 – IEC 60079-0
DIN EN 50016 (VDE 0170/0171 part 3),
DIN EN 60079-2 – IEC 60079-2
DIN EN 50019 (VDE 0170/0171 part 6),
DIN EN 60079-7 – IEC 60079-7
DIN EN 50021 (VDE 0170/0171 part 16),
DIN EN 60079-15 – IEC 60079-15

On request, the products can be supplied in accordance with other standards, such as IEC standards currently being ratified, as well as in accordance with special industry regulations, such as ZLM (additional supply agreements for high-voltage electrical motors in power plants), regulations from all of the major ship classification associations or the Shell specification.

4. Synchronous motors for constant-sped applications



4.1 Voltage and frequency
In the basic design, the motors are dimensioned for a rated voltage of 6 kV and a rated frequency of 50 Hz, with a power factor of cos φ = (0.9 ever-excited).

Voltage and frequency fluctuations during operation are possible in agreement with the stipulations in DIN EN 60034-1 (VDE 0530 part 1), IEC 60034.

Motors for voltage ranges ≤ 3.3 kV have higher, motors for voltage ranges > 6.6 kV lower rated outputs with the same construction models.

4.2 Rated power output and heat generation
The rated outputs stated in the summary of supply hold for continuous operation (S1) at rated frequency, rated voltage, installation altitude ≤ 1,000 m above sea level and a maximum cooling air entry temperature of 40°C or cooling water entry temperature of 27°C. The maximum winding temperatures correspond to thermal class B in accordance with DIN IEC 60085 (VDE 0301 part 1), IEC 60095, measured using the resistance method.

Motors can be supplied with a maximum permissible temperature rise in accordance with thermal class F.

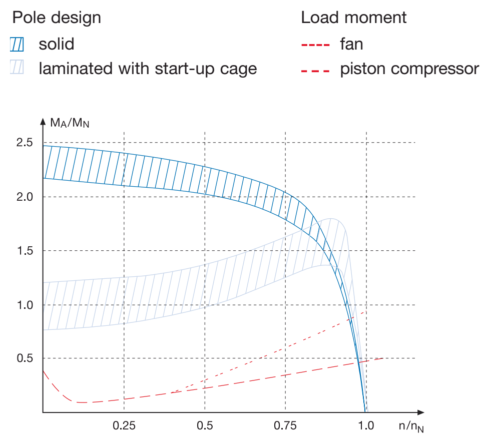
4.3 Direction of rotation
As a general rule, the synchronouse motors must only be operated in the agreed direction of rotation. Special fans can be used in cases requiring bi-directional operation. Fans for bi-directional operation cause greater frictional losses and therefore achieve a lower efficiency.

4.4 Overload capacity
The synchronous breakdown torque is 1.5 / 1.35 times the rated torque for salient-pole motors and smooth-core rotor motors respectively.
Depending on the drive task in hand, these values can be modified.

4.5 Start-up
The motors are designed for a direct start-up. In principle, reduced start-up current can be achieved by:
- reducing the stator voltage with an autotransformer or reactance coil.
- frequency start-up

The parameters of the machine need to be quoted in all cases so that the start-up conditions can be assessed, including:
- load moment curve (from idling to rated speed)
- mass moment of inertia
- maximum permitted mains voltage breakthrough during the start-up phase
- number of start-ups in direct sequence

4.6. Modifications
- Rated voltage up to 13.8 kV
- 60 Hz or other rated frequency
- Power factor control
- Large-scale and special motors for rated torques of up to 2,000 kNm
- Air-to-air hear exchanger
- Start-up with additional resistor in the rotor circuit for difficult start-ups
- Explosion-proof version



$M_A/M_N = f(n/n_N)$

Schematic diagrams of the start-up torque depending on pole design.

5. Converter-fed, variable-speed synchronous motors

Synchronous motors with variable speed control are used in a wide variety of industrial applications. Synchronous motors with a rated power output in excess of 1 MW have established themselves ahead of DC drives particularly in rolling mills, on ships and in the chemical industry.

The advantages of synchronous machines include:
- greater power and speeds can be achieved with the engine
- robust design which is adapted to the drive tasks
- low-maintenance operation
- high degree of efficiency
- speed setting can be used with a wide field suppression range
- commutation reactive power (load-controlled inverter) can be taken over

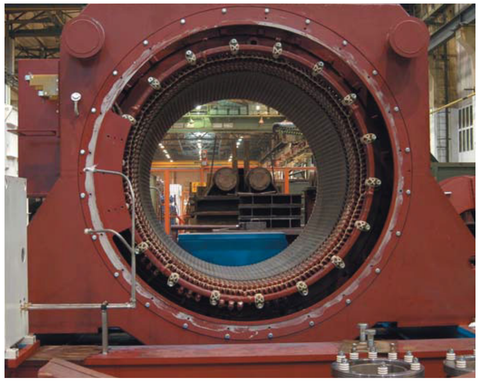
Design concept
In contrast to conventional synchronous machines, the design of converter-fed machines also takes the following aspects into account:
- dimensioning of the stator winding insulation for operation on a direct converter or indirect converter and the relevant rated voltage
- dynamic and quasi-stationary overload torques on rolling mill motors
- adaptation of the electromagnetic parameters to the special requirements of speed-controlled drives
- additional insulation of the bearings on the D end and spindle grounding brush depending on the type of converter used.

Depending on the system components and drive-specific requirements, the motors can be implemented in the form of smooth core rotor motors or salient-pole motors, or with/without brushes.

The operation of the motors on frequency converters results among other things in a higher noise level than with sinusoidal mains power networks. In the case of converters, the increase in the acoustic pressure level depends on:
- converter type
- pulse frequency
- pulse pattern
- output filter

In the case of converter-fed machines, the converter type must be stated in the inquiry.

Synchronous motor for frequency converter operation, rolling mill drive, type DMMYZ 8044-6Y



Stator for rolling mill drive, type DMMYZ 2246-6Y

6. Design description

6.1 Stator
The stator housing is a welded construction comprising end walls and intermediate walls with support ribs, bars and sheet casing. It stands on base plates on the foundations.
The stamping pack consists of insulated dynamo sheet round plates or overlapped layered dynamo sheet segments, and it is axially tensioned over end plates with press pins and welded-on bars. On machines with a diameter of up to 4,000 mm, the stamping pack is wound with whole pulled coils, fully impregnated according to the VPI process and shrink-fitted into the stator housing.
On larger machines, the insulated dynamo sheet segments are overlapped and layered on guide bars in the housing, tensioned and then wound with vacuum-pressure impregnated transposed conductor rods or pulled coils which are premanufactured according to the resin-rich process.
The three-phase stator winding lies in the open slots of the stamping pack. Depending on the rated power output, it is implemented as a double-layer whole pulled coil or double-layer transposed conductor winding.
With the whole pulled coil, the conductive material is made of flat copper wire which is insulated with mica foil. For the conductors of the transposed conductor winding twisted in the slot part, lacquer-fibreglass-insulated flat copper wires are used and fastened as a wire bundle with mica-prepreg.
The main insulation of the coils or rods consists of mica-fibreglass tape. To avoid corona discharges, a low impedance mica protective cover is installed in the slot part and a high impedance protective cover is installed in the slot exit.
The fully insulated conductor packages are fixed in the slots using slot connectors.
The winding heads are safely supported against the mechanical loads arising during switching operations due to binding, spacer pieces or retaining rings.
The switch connections are hard-soldered at the whole pulled coil winding; in the case of transposed conductor windings, the rod connections are made through TIG-inert gas shielded arc welding.

6.2 Rotor

6.2.1 Rotor types

The rotor type and the pole design depend on the machine size, the speed, the number of poles and the drive tasks in hand. The standard variants are:

Synchronous motor
- Salient-pole version
  - Solid poles
  - Laminated poles
- Smooth-core rotor (laminated)

Smooth-core pole design

With smooth-core poles, high-speed motors with a relatively low mass moment of inertia can be achieved.

Laminated salient pole design

Laminated salient poles with damper windings are primarily used for high-pole motors with a mid to high-range power output.

Solid pole design

The solid pole design is mostly used for larger motors which operate at higher speeds. This design is mechanically robust and, thanks to the large heat capacity of the pole cover, it enables an asynchronous start-up with relatively large external mass moments of inertia.

6.2.2 Description of the design and layout

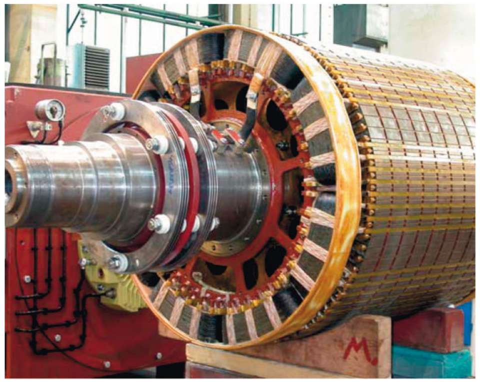
The rotors can be designed as smooth-core rotors or salient-pole rotors.

Salient-pole rotor

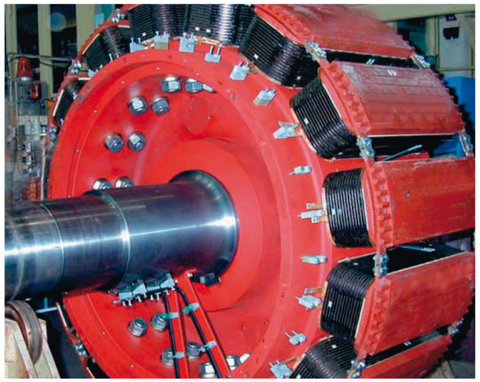
The stamping pack, which is made of insulated dynamo sheet round plates, is shrink-fitted to a forged spindle. The stamping pack is axially loaded with insulated with press pins.
With larger synchronous motors, spider shafts are used, on to which the rotor plate segments are positioned and keyed.
The excitation winding is laid into the slots of the stamping pack. Lacquer-fibreglass-insulated profiled wires are used for the excitation winding. The rotor is fully impregnated in accordance with the VPI method.
Slots are distributed evenly around the outer circumference of the rotor stamping pack to take the start-up rods. The start-up rods are hard-soldered at the ends with short circuit discs. They also form the short circuit cage for direct start-ups.
For start-ups with relatively high mass moments of inertia or with high load moments, specially designed high-rod start-up cages are used.
Special designs are used to stabilise the rotor winding in applications with special operating loads, e.g. rolling mill drives.

Salient-pole rotor in solid pole design

The spindle with the pole cores consists of a forged piece which is machined on all sides. Pole coils made of edge-wound flat copper are positioned with insulation on the pole cores.
In order to improve heat dissipation and mechanical stability,



Smooth-core rotor for rolling mill drives,
type DMMYZ 8027-8W



Salient-pole rotor, laminated, for piston copressor drive
type DTKVY 2523-16WS

they are cast in resin. Forged pole covers are screwed onto the pole cores.

Salient-pole rotors with laminated poles

A cast rotor body is drawn onto a forged spindle or flanged onto a forged spindle.
The poles are made of layered plates, then pressed onto the end plates and secured with bolts. The poles are wound directly with insulated flat copper wire and VPI impregnated.
Alternatively, insulated pole coils, which consist of edge-wound flat copper, are set onto the pole cores and cast in resin to improve heat dissipation and mechanical stability. There are additional slots on the pole covers which take the start-up rods.
The complete poles are screwed onto the rotor bodies, or they are attached with hammer head grooves and wedges under high circumferential forces. The ends of the start-up rods are short-circuited with segments.

6.3 Connecting boxes

All connecting boxes are designed to protection class IP55 in their basic designs.

Wiring connecting box

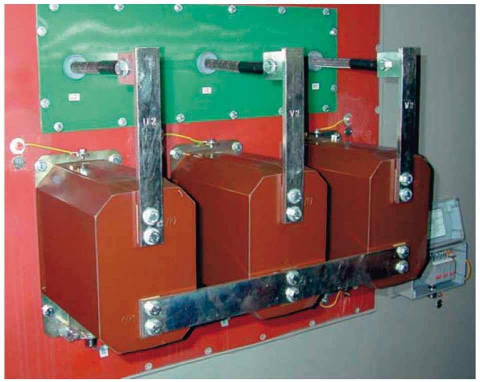
The wiring connecting box is positioned on the side wall of the stator housing.
The box features a welded 2-part design. The lower part is bolted to a plate which makes up part of the housing. There is a designated breaking point in the lower part which is designed to relieve pressure in the event of a short circuit.
Bores in the lower part take short-circuit proof cast resin insulators which contain duct bolts which are secured against rotation.
They are soldered to the cable to the cable outlets of the stator winding. The connection on the mains side is provided by means of cable sleeves which are screwed to the duct bolts. The cable outlet is to the bottom. Screw-type cable connector terminals are used on single-conductor cables. A special module is used for three-conductor cables containing sealing rings which can be cut out and a pull-relief pressure ring.

Start point box

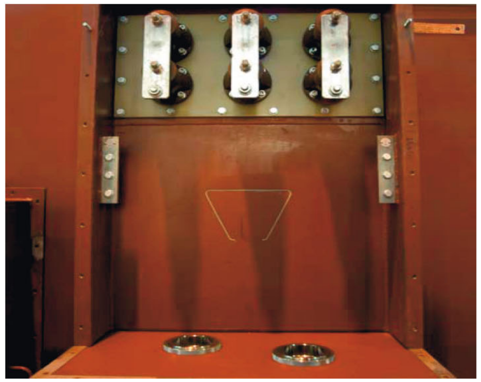
The star point can be located in a second box opposite the cable connecting box. Current transformers can be installed on request (not on EEx e applications).

Auxiliary connecting box

Additional connecting boxes for connecting excitation devices, monitoring devices, anti-condensation heaters etc. are positioned on the stator. They are made of a low-corrosion cast aluminium alloy. The cable outlets are provided via screw-type terminals.



Connecting box, with outgoing star point with current transformer for differential protection



Stator connecting box

6.4 Bearings

The type of bearings used depends on the requirements resulting from the mechanical loads and the machine which is to be driven. As a general rule, an attempt is made to ensure maximum operational safety and reliability and maximum service life.

Rolling bearings

The motors are equipped with DIN-standard rolling bearings. A deep groove ball bearing is used as a guide bearing on the D end. At absorbs the radial and (low) axial loads. A cylinder roller bearing is used as a floating bearing on the ND end. Under increased mechanical loads and higher speeds, the deep groove ball bearing on the D end is reinforced with a cylinder roller bearing. At lower speeds, a deep groove ball bearing is used at the ND end instead of the cylinder roller bearing as a floating bearing in an axial position. In applications where the synchronous motor is designed to absorb additional axial loads, a special bearing with pre-loaded angular contact ball bearings is used.
The axial loads and radial loads should be quoted in the request / specification.

All rolling bearings are lubricated with lithium-base-saponified grease of consistency class 3.

The bearing modules are equipped with an automatic grease quantity control system. This ensures perfect lubrication levels after re-greasing.
In accordance with the specifications in the motor documentation, the bearings must be regularly re-greased with the indicated type and quantity of grease in order to make sure that the bearings achieve their nominal service life. This is done using M10x1 flat grease nipples in accordance with DIN 3404.

The bearings for smaller synchronous motors are equipped with a storage receptacle for the old grease. Provided the proper re-greasing schedule is followed, this receptacle is large enough for the calculated service life of the bearings. Bearings for larger motors have storage receptacles for old grease which can be emptied from outside.

The bearings are sealed to the inside of the motor and to the outside with gap seals. They are maintenance-free and protect against penetration of dust and water. The bearing heads on the ND end are insulated against the motor housing to prevent bearing currents.

The rolling bearings are monitored via Pt100 temperature measurements. Versions can be implemented with vibration monitoring.

Rolling bearings

Sliding bearings

Sliding bearings

Depending on the design of the machine, the sliding bearings can be designed as flange bearings or as pedestal bearings, or they can be centred on the end plate.
The types of bearing used include bearings with a split housing, split bearing shells and split lubricating rings and sealing rings. This enables bearings to be serviced and sealing rings to be replaced without the need for disassembly of adjacent motor component groups or couplings.

The protection class of the bearings in their basic design is IP 44. Higher protection classes (IP54 or IP55) can be achieved by using additional seals/gaskets.
The bearing shell of the sliding bearing on the ND side is insulated to prevent bearing currents.

The sliding bearings are usually designed as floating bearings, i.e. the motor rotor is guided via a coupling with limited axial clearance by the supporting bearing of the machine. It is also possible to use a locating bearing if no axial forces are directed from the machine or coupling onto the motor spindle. Special bearing shells are used for applications where axial forces need to be absorbed.

The sliding bearings are preferably cooled via heat dissipation through the surface of the bearing housing. If the operating conditions do not allow this, then the bearings can also be cooled with rinsing oil or via an integrated water cooler. At low speeds or in applications with greater rotor masses, a hydrostatic rotor boost is used.

Lubrication is provided by means of lubricating oils with a viscosity class which is governed by the operational data of the sliding bearing. Use of other oils must be agreed with VEM.

Appropriate oil supply units are available from VEM for the use of rinsing oil to cool the bearings.

The bearing shells on the ND end are insulated to prevent bearing currents.

Monitoring is preferably implemented via Pt100 temperature measurements. A version with vibration dampers is available. For connection to a rinsing oil system, we can supply choke screws (which are used to control the flow rate of the oil) and a flow rate display unit or monitor.

6.5 Cooling
The machine is air-cooled inside. The air is either pumped axially or radially through the rotor and stator via fan wheels which are attached to the spindle (self-cooling) or via additional add-on fans with a motor (forced ventilator). In the process, the air absorbs waste heat from the stamping pack and the windings.
The choice of cooling method depends on the overall plant project and is primarily governed by the required protection rating and the available media. Standard cooling methods include:

Open cooling circuit (up to protection rating IP23)
Ambient air is used as cooling air. Once it has cooled the machine it is discharged back into the atmosphere.
Appropriate shutters are used to ensure that the required protection rating is attained.

Closed cooling circuit with connected heat exchanger (protection rating IP44 and above)
The cooling air inside the motor is pumped to a closed circuit (primary circuit), where it discharges its heat via a heat exchanger to a cooling medium (secondary circuit). Air-to-water or air-to-air heat exchangers are used.
In the case of air-to-water heat exchangers, the pipe material used is governed by the quality of the cooling water. Double-pipe versions and versions with water leakage warning systems and flow monitors are also available.
In the case of air-to-air heat exchangers, the outside air is pumped through the heat exchanger by means of additional forced ventilators.

6.6 Closed-loop control
6.6.1 Integration into E-systems
When the synchronous motor is operated directly off the mains supply, the excitation unit represents the control link between the E-system and the motor. This applies to both brushless and static excitation systems which have analogue or digital excitation control. Depending on the size of the motor and the configuration of the E-system, a greater or lesser number of control functions are performed or assessed by the excitation unit.
Key features of the synchronous machine are achieved through open and closed-loop control of the excitation, as a result of which the scope of functions of the excitation unit may vary to a great extent depending on the specific requirements from the plant project.
Excitation control functions are used among other things to influence the start-up behaviour, the stability during non-stationary processes and the re-synchronisation behaviour.
The open-loop excitation control enables the following functions to be implemented within the program:

- Anti-blocking protection
- Start-up monitoring
- (Deliberate) synchronisation
- Crank angle control
- Triggering of protection systems
- Asynchronous running protection with re-synchronisation
- Setpoint adjustment
- Controller status control (Auto/Manual…)
- Warning and error message displays
- On-site controls via operator panel
- Rotating diode monitoring
- Controller monitoring
- Rotor ground fault monitoring

The exchange of signals for plant control purposes takes place digitally via the mutual provision of potential-free relay contacts or relay coils. The exchange of analogue signals takes place via potential-free coupling blocks with standardized current or voltage outputs. Other methods for exchanging signals, such as serial bus links, can be modified to suit specific requirements.

6.6.2 Excitation cabinet
The excitation unit is usually laid out as a switching cabinet, on static installations also as a combination of several switching cabinets. On simple devices for low-power applications, other designs can also be supplied, including motor attachment, wall attachment or assembly plate attachment. The cabinet properties are adapted according to the specific requirements of any given application.
The steel control cabinet contains the entire open and closed-loop excitation control systems. An inspection window on the front door is available on request to provide a view of the important measuring instruments and displays. A bottom plate with PG screw fastenings can also be supplied for the cabinet, which is otherwise open at the bottom.

Switching devices and, if applicable, the power section are located on the assembly plate in the rear of the cabinet.

The open and closed-loop controllers are mounted on a pivoting frame. The pivoting frame is omitted on smaller units. In this case the open and closed-loop controllers are also housed on the assembly plate.

6.6.3 Function of the excitation system
In principle, the closed-loop control of a synchronous motor via its excitation takes place under the aspects of drive stability and the specific requirements of the E-system or mains supply. Although these aspects are not mutually exclusive, the configuration of the overall system should be carefully balanced in both their favour.

Closed-loop reactive power control is generally utilised, which operates with a subordinate (auxiliary) excitation current control on brushless systems, as this provides good settling times. As an alternative, cosj control can also be used as a derived form of reactive power control.

Measured values which are only indirectly connected to the synchronous motor can also be used as the actual values for the controller, as a result of which the behaviour of the entire network island is influenced. Similar effects can also

Open cooling circuit

Closed cooling circuit (air-to-air)

Closed cooling circuit (air-to-water)

be achieved variable setpoint specifications which are generated in a higher level control.

A range of limiting controllers are used primarily to prevent a loss of stability of the motor.

The limitation of the rotor displacement angle is based on a system of detecting the angle via inductive sensors in the motor.

The excitation current control serves for servicing and manual operation purposes, as well as for simple operation from a higher level control. In the process, the internal setpoint is adjusted via HIGH/LOW signals.

Depending on the project requirements, more or less complex analogue or digital devices are used.

Basic functions:
- Reactive power control
- Digital setpoints
- Manual operation
- Excitation current control
- Limitation of excitation current
- Limitation of over and under-excitation

Possible upgrades:
- Remote setpoint processing
- External actual value processing
- Limitation of rotor displacement angle
- Stator current limitation
- Reactive power limitation

Other functions required in addition to the above should be discussed with VEM.

6.7 Excitation

The synchronous motors are supplied as brushless versions as standard.
Alternatively, excitation via a slip ring arrangement is also available.

The brushless version is maintenance-free and can also be used when the motor is operated in an atmosphere with an increased risk of explosion.

The rotating brushless excitation unit (excitation machine, rectifier, start-up thyristor, protective circuitry and, if applicable, start-up resistor) can be arranged both inside and outside the machine.

Excitation cabinet

Depending on the required mode of operation for the motor, the excitation machine is laid out as either
- a three-phase rotating armature excitation machine with DC supply on the stator side, or
- a three-phase excitation machine with three-phase current supply on the stator side.

The rotor of the excitation machine supplies the excitation power to the excitation winding of the motor via rotating rectifier modules which are connected in a three-phase bridge connection.

6.7.1 Description of the design and layout of the excitation machine

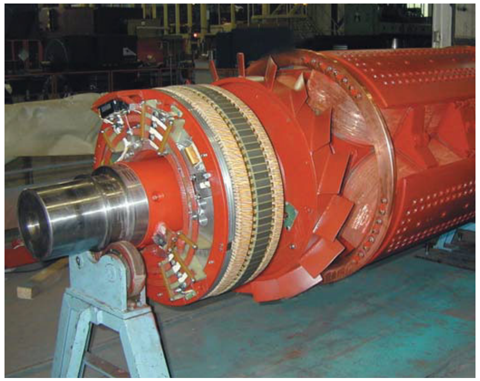
The excitation machine is a three-phase external pole generator, the rotor of which is mounted together with the diode bridge and protective circuitry on a hub. This unit can be pulled off the spindle with minimal installation effort in terms of the excitation stator.

The stator of the excitation machine is supported by the end plate on the ND side, or it is supported by a supporting star on larger machines. The stator consists of a stamping pack made of insulated dynamo sheet round plates with stamped-out poles. These poles carry a DC winding. If the synchronous machine is intended to be operated with a frequency-controlled start-up, then the excitation stator is laid out with a three-phase winding.

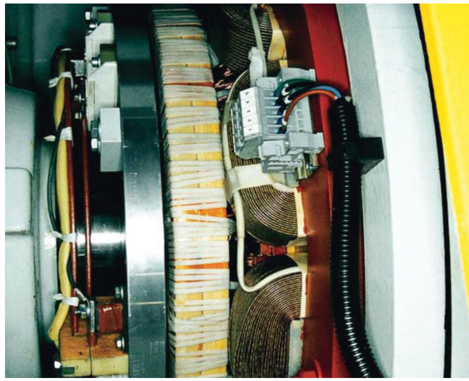
The rotor of the excitation machine is located on the rotor, where it is pulled on over a bush. The rotor has a stamping pack made of insulated dynamo sheet round plates with a three-stranded three-phase winding. A 6-pulse bridge circuit rotates together with the rotor to rectify the voltage induced in the excitation rotor. The output of the bridge is branched off to the excitation coil of the rotor.

6.7.2 Start-up on the converter

The power supply to the stator winding of the synchronous motor is provided from the mains supply via a converter. The latter features a complex open and closed-loop controller which regulates the required output voltage of the converter according to the current operating point of the motor.
In addition, the optimum excitation current for the excitation machine is also usually provided by the converter unit via a three-phase power controller. The excitation machine acts as a transformer during start-up. With increasing speed, this mode of operation is superseded by generator operation.
In order to supply the voltage to the motor excitation winding, there is a three-phase diode bridge on the output of the rotor winding which is terminated on the DC side with a varistor or RC circuit to reduce transient voltage peaks.



Salient-pole rotor with excitation machine



Rotor and diode bridge of the excitation machine

Depending on the application, the converter is only used during start-up. In the process, the power rectifier is bridged once mains synchronism is attained, as a result of which the motor is run directly off the mains. This means that the converter is only called upon during start-up, with the corresponding implications for dimensioning. Closed-loop excitation control is also provided by the converter complex during synchronous mains operation.

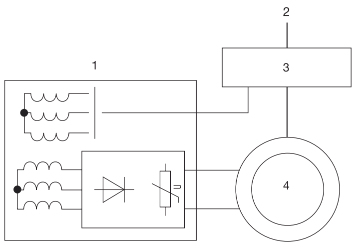
6.7.3 Asynchronous low-load start-up

In the event of operation without supply from a converter and with a relatively low load moment, the brushless synchronous motor can also start up asynchronously, provided provisions are in place in the rotor circuit for the AC start-up current in the excitation coil.

The positive half-wave of the AC start-up current flows through the rectifier diode bridge which is already in place. The negative half-wave flows anti-parallel through voltage-controlled thyristors to a diode branch of the rectifier bridge.
The voltage-controlled triggering of the thyristors is achieved by virtue of the current-forcing character of the AC start-up current.
The thyristors are reliably turned off during operation by being connected to the AC voltage of the excitation machine by means of voltage zero.

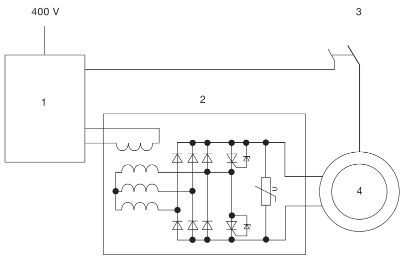
6.7.4 Asynchronous high-load start-up

To start up the synchronous motor without a supply from a converter against a relatively high load moment, the excitation coil must be terminated with an optimised start-up ipedance. This has the effect that the asynchronous moment of the moment is increased, pull-up torques are prevented and tendencies to vibrate are significantly reduced. If the start-up impedance was to remain connected after synchronization has taken place, additional losses would be encountered. Suitable circuit connections are implemented to prevent permanent connection of the start-up impedance even with brushless excitation. At the same time, this method also achieves deliberate synchronisation. This synchronisation generates a very good synchronising moment and also enables the so-called crank angle control.
Depending on polarity, the AC start-up current flows either through a diode or a voltage-controlled thyristor via the start-up impedance in the rotor circuit, whereby the series-thyristor remains untriggered.
When the minimum slip is reached, the rotor displacement angle is sensed in order to connect the excitation voltage to the excitation coil by triggering the series thyristor. In the event of an overload, the sufficiently high slip component of the excitation current switches off the series thyristor, allowing the motor to be re-synchronised once the minimum slip is reached again.



1 exciter
2 mains
3 converter
4 motor

Schematic diagram showing a rotor with connected converter



1 exciter-regulator
2 exciter and rectifier bridge
3 mains
4 motor

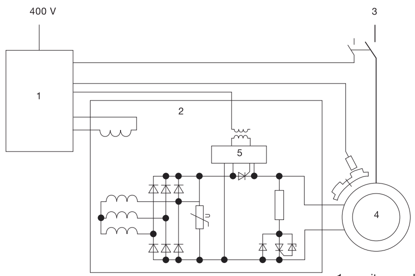
Rotor circuit diagram - asynchronous low-load start-up

6.7.5 Static excitation

As an alternative to the brushless excitation method, a static excitation device can also be used.
The advantages of this method are: direct access to the excitation circuit, omission of the auxiliary excitation time constant and comparatively highly dynamic response of the control system.
The necessity of slip rings for transferral of the excitation current, the higher auxiliary power requirements and the additional expense of the excitation current actuator, which is balanced by the omission of the excitation machine, all need to be taken into account.
There are no differences between the brushless and static excitation systems in terms of open and closed-loop control functions. The choice of which system is used depends primarily upon the varied requirements of the site where it is to be used, although the brushless excitation system is generally the standard choice.

Slip ring arrangement

The brush bridge consists of a brush carrier to which insulated brush pins with brush holders are attached. The brush carrier is supported by the end plate on the ND side, or it is supported by a supporting star on larger machines.
A slip ring body is shrink-fitted to the spindle, and this in turn takes the slip rings which are made of stainless steel. There are branch-off conductors made of round copper on the slip rings which lead to the excitation coils of the rotor.



1 exciter-regulator
2 exciter and rectifier bridge
3 mains
4 motor
5 firing

Schematic circuit diagram showing the rotor during a heavy-load start-up

7. Explosion-proof motors

Special regulations and directives apply to the setting-up of motors in explosion-hazardous areas in which dangerous concentrations of explosive atmospheres can build up. The areas are divided into zones (EN 60079-10 (VDE 0165 part 101), IEC 60079-10) and the production tools, i.e. the electric machines as well, are divided into device categories or ignition protection types. All European manufacturers must comply with the ATEX guidelines, which became legally binding as of 1 July 2003.

Depending on the conditions at the location of use, Sachsenwerk motors are delivered in accordance with DIN EN 50014 (VDE 0170/0171 part 1), DIN EN 60079-0 – IEC 60079-0 with the following types of ignition protection:

- increased safety “e” (in accordance with DIN EN 50019 (VDE 0170/0171 part 6) and IEC 60079-7 – IEC 60079-7) – on request
- pressurisation „p“ (in accordance with DIN EN 50016 (VDE 0170/0171 part 3), DIN EN 60079-2 – IEC 60079-2)
- sparkless in normal operation „n“ (in accordance with DIN EN 50021 (VDE 0170/0171 part 16), DIN EN 60079-15 – IEC 60079-15)

The fundamental safety requirements for explosion-proof motors in ignition protection type „e“ as per IEC 60079-7 are increased considerably compared to the previous design according to DIN EN 50019 so that, in the stage of contract preparation, a risk evaluation of possible ignition dangers should be conducted, and measures to minimise risk should be adopted if applicable.

For high-voltage machines with rated voltage $U_N \geq 6$ kV, a system test for the complete insulation system under an ignitable atmosphere remains necessary. The corresponding certificate of the PTB-Braunschweig as a recognized test authority is available for a Sachsenwerk insulation system VEMoDUR-VPI-155.

Scavenging air control system (EEx p)

Synchronous motor, 3.5 MW extruder drive (EEx p)

8. Universal VEMoDUR insulation system

The operating reliability of electrical machines is determined to a large extent by the quality of their winding insulation. The insulation technology at Sachsenwerk has always been characterised by technical solutions which, in terms of their quality parameters, meet applicable international standards and thus ensure products which are highly reliable and offer their operators a long service life.

The VPI technique (vacuum pressure impregnation) is used for high-voltage machines. The associated insulation system VEMoDUR-VPI-155 was developed at Sachsenwerk and is registered as a trademark . The designation “VEM” stands for “Vereinigter Elektromaschinenbau” and “DUR” for the duroplastic behaviour of the insulations with synthetic adhesives that are used.

This system contains the following listed main components for the stator windings:

Winding insulation	⇒ mica foil bands
Main insulation (groove and core chuck)	⇒ mica-fibreglass bands (contains accelerator, low adhesive)
Impregnating material	⇒ epoxy resin

The components are optimally matched to each other. The insulation class F has been confirmed through many years of operating experience and functional evaluation as per DIN EN 60034-18-31 (VDE 0530 part 18-31) - IEC 60034-18-31. To guarantee the quality of the insulation system, all components are subjected to a receipt inspection in accordance with DIN EN ISO 9001 – ISO 9001.

During the impregnation process, the insulation is subjected to a constant control system, whereby characteristics such as:
- viscosity of the resin
- impregnation and curing temperature
- pressure maintaining times
- under- and overpressure
- pressure impregnation
- are checked and documented.

The insulation is cured in rotation.

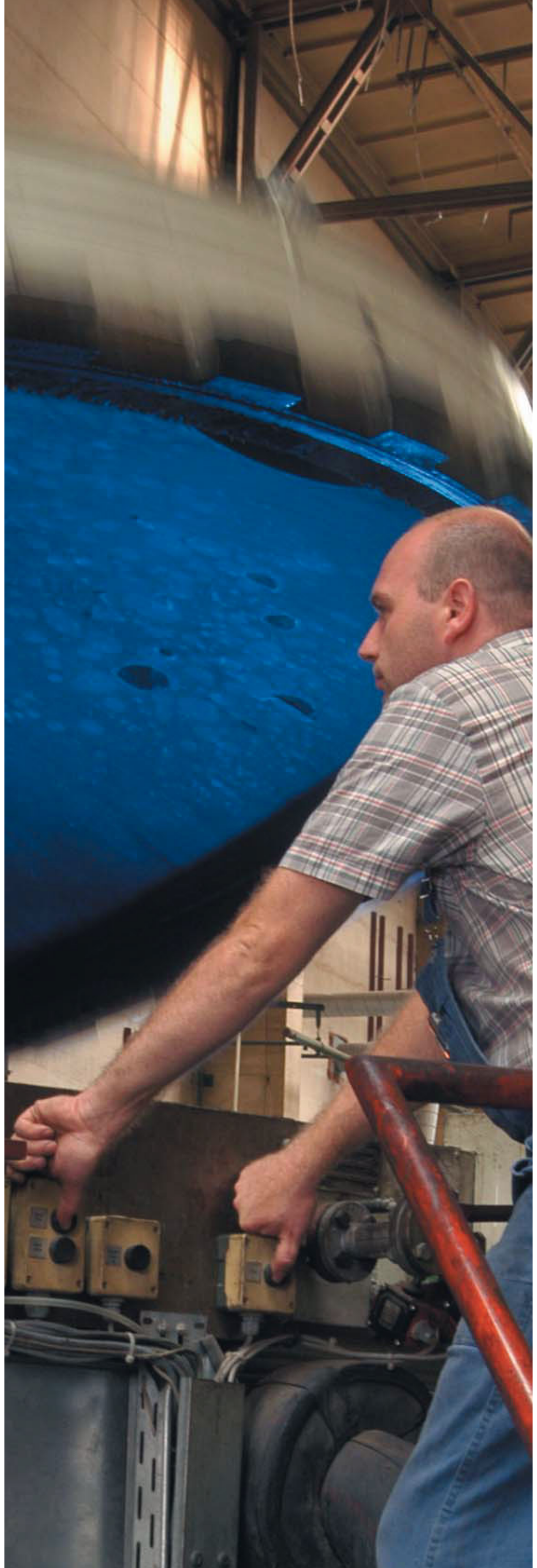
Vacuum-pressure impregnation guarantees a high mechanical strength (core chuck rigidity) and outstanding electrical strength. This holds especially for the distance sparkover voltages. Rated surge voltages in accordance with DIN EN 60034-15 (VDE 0530 part 15) – IEC 60034-15 are guaranteed for all machines with a great degree of reliability (see table extract).

Insulation level of rotating electrical machines with stator pulled coil windings in accordance with DIN EN 60034-15 (VDE 0530 part 15) – IEC 60024-15 (extract)
The insulation system is highly resistant to climate influences,

Rated voltage U_N in kV	Rated surge voltage (peak value) in kV Shaft 1.2/50 ($4U_N$ + 5 kV)	Mains frequency testing voltage (effective 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

VEM can also supply special designs with increased rated surge voltages on customer request.

Example: U_N = 11 kV
Main insulation: 80 kV
Winding insulation: 60 kV



The insulation systems is highly resisitant to climate influences, i.e. the winding is not sensitive to humid or aggressive atmospheres.

The VPI insulation system represents the standard design.

The technically equivalent resin-rich insulating system is used on very large machines. With this system, resin-rich mica fibreglass insulating bands are bound onto the main insulation and the winding head insulation and then hardened in the slot part under pressure and heat.

Within the framework of internal quality inspection in accordance with DIN VDE, electrical interim and final checks of the insulation strength are performed together with (on customer request) surge voltage and partial discharge level tests. This ensures a quality that meets market demands and competitive requirements.

The VEMoDUR insulation system is also suitable for machines with "increased safety" ignition protection type EExe in accordance with DIN EN 50019 (VDE 0170/0171 part 6) as well as Exe as per IEC 60079-7 – IEC 60079-7.

9. Inspections

An effective quality assurance and management system guarantees the optimal value and quality of the motors. Every motor is subject to an internal individual inspection. The results of the inspections are documented in an inspection log. This is part of the delivery documentation.

Individual inspections
- Visual inspection (identification, completeness, condition of construction, quality of assembly, brush type and dimensions etc.)
- Air gap measurements (if permitted by the construction)
- Insulation resistance of the windings, temperature probes, anti-condensation heaters, bearings (inspection performed during assembly)
- Ohmic resistances of the windings, temperature probes, anti-condensation heaters
- Measurement of the magnet wheel impedance
- Setting of the magnetic centre for sliding bearings
- Idling characteristic curve for determining magnetic and frictional losses, calculation check of efficiency, if required
- Check of direction of rotation
- Inspection of the voltage geometry
- Winding checks
- Vibration severity measurement
- Short-circuit characteristic curve and loss measurement (generator method)
- Determination of the SPM level (if corresponding feature is available)
- Current overload test
- Winding check (high voltage test)
- Functional capability of the accessories

Type inspections
If the customer wishes, additional inspections can be performed within the scope of the type inspection. The additional costs will be charged to the customer. In this case, the following inspections are conducted in addition to the individual inspection:

- Overspeed test
- Recording of the idling characteristic curve and loss measurement
- Noise measurement at idle
- Wave voltage measurement on machines with insulated bearings (if permitted by the construction)
- Degree of distortion of the voltage curve
- Measurement of the THF factor
- Reactances and time constants – determination of the residual voltage
- Short-circuit characteristic curve and loss measurement (motor method)
- Surge short-circuit check
- Load characteristic
- Control characteristic
- Determination of the nominal excitation current
- Determination of the degree of efficiency
- Air quantity measurements, pressure losses
- Thermal test with rated data or substitute tests
- Anti-condensation heating
- Thermal time constants, load limit determination
- Cooling time constants
- Runout measurement, determination of the mass moment of inertia
- Runup measurement, determination of the start-up characteristics
- Determination of the key variables of the synchronous machine
- Measurement of the SPM level
- Operating characteristic curves $\eta = f(P_{el})$, $\cos \varphi = f(P_{el})$, $P_{mech} = f(P_{el})$, $s = f(P_{el})$, $I = f(P_{el})$

10. Documentation

Unless agreed otherwise, the „Operation and Service Manual“ documentation contains the following documents:
- Safety instructions
- EC manufacturer’s declaration
- Description / technical data
- Dimensional drawing of motor
- Dimensional drawing of cable connections
- Connection plans for temperature monitoring, anti-condensation heaters
- Installation / assembly
- Commissioning
- Operation
- Maintenance
- Servicing
- Replacement parts list
- Test certificate / log book
- Supplemental operation manuals (options, third-party suppliers)

Any additional documentation beyond this scope must be agreed by contract.

The documentation is provided in two copies when the product is delivered. It is available in all EU languages.
VEM charges for costs of additional copies, additional documentation, and translation into other languages.

11. Shipping, packaging, installation

The type of packaging is determined at the time of contract according to the transportation and storage conditions specified in the order and takes into account the design and construction of the machines. VEM can offer all types of special packaging and provide shipping and installation of motors to any destination worldwide.

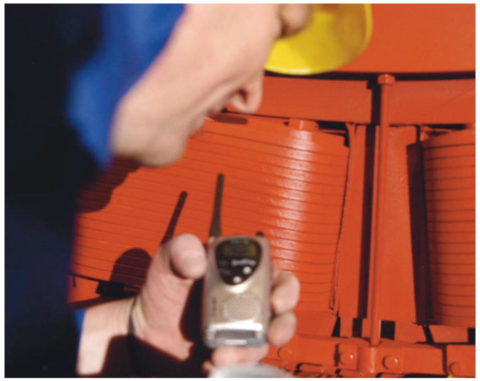
The machines are shipped either fully assembled or disassembled depending on the size and contractual agreements.

VEM recommends the installation and commissioning service of our specialist personnel.

If the customer prefers to perform the installation and commissioning themselves or have this work done by a third party, then the performance of this work must be verified in section 9 (test certificates, logbook) of the VEM Operation and Service Manual, or by other means. Failure to comply with this requirement will absolve VEM from any liability or warranty obligations.

The VEM Operation and Service Manual is delivered with the machine.

If contractually agreed, the documentation can also be sent separately to the buyer or operator.



12. General instructions

If not expressly requested and offered otherwise, the machine is designed as follows:

- It is built with the insulation system VEMoDUR.
- It is painted in accordance with Sachsenwerk Standard SW-N 170-004, which is based on DIN EN ISO 12944 ... – ISO 12944... and applicable standards.
- The machine’s direction of rotation is right, when looking at the drive (D) end. The connecting box is positioned on the right.
- The cooler is located on the machine and the water connection is on the left when looking at the drive (D) end.
- Water cooler up to the connecting flange without monitoring on the water side.
- Without cable stuffing socket.
- PT 100 for winding and storage in 2-wire switch without trigger device, from terminal box connection in 2-, 3- and 4-wire design.
- Mechanical vibrations correspond to the limits specified in EN 60034-14 and are proved in the test lab.
- Vibration monitoring is performed without an evaluation device.

13. Technical data

Power range
Brushless high-voltage synchronous motors 6 kV
50Hz · cos φ = 0,9ü · Number of poles 4-12 · Thermal class F (utilization B)

Typ DT…	Centre height (mm)	Power output 1500 min^{-1}	1000 min^{-1}	750 min^{-1}	600 min^{-1}	500 min^{-1}
4516	450	800	560	400	-	-
4519	450	1000	710	500	-	-
5018	500	1250	900	630	500	400
5023	500	1600	1120	800	630	500
5621	560	2000	1400	1000	800	630
5627	560	2500	1800	1250	1000	800
6321	630	2800	2000	1400	1120	900
6324	630	3150	2250	1600	1250	1000
6327	630	3550	2500	1800	1400	1120
6329	630	4000	2800	2000	1600	1250
7125	710	4500	3150	2250	1800	1400
7127	710	5000	3550	2500	2000	1600
7130	710	5600	4000	2800	2250	1800
7133	710	6300	4500	3150	2500	2000
8030	800	7100	5000	3550	2800	2250
8033	800	8000	5600	4000	3150	2500
8036	800	9000	6300	4500	3550	2800
8040	800	10000	7100	5000	4000	3150
9033	900	11200	8000	5600	4500	3550
9036	900	12500	9000	6300	5000	4000
9040	900	14000	10000	7100	5600	4500
9045	900	16000	11200	8000	6300	5000
1038	1000	18000	12500	9000	7100	5600
1042	1000	20000	14000	10000	8000	6300
1047	1000	-	16000	11200	9000	7100
1053	1000	-	18000	12500	10000	8000
1148	1120	-	20000	14000	11200	9000
1153	1120	-	-	16000	12500	10000
1158	1120	-	-	-	-	-
1164	1120	-	-	-	-	-

Power range
Brushless high-voltage synchronous motors 10 kV
50Hz · cos φ = 0,9ü · Number of poles 4-12 · Thermal class F (utilization B)

Typ DT…	Centre height (mm)	Power output 1500 min^{-1}	1000 min^{-1}	750 min^{-1}	600 min^{-1}	500 min^{-1}
-	-	-	-	-	-	-
-	-	-	-	-	-	-
5018	500	1120	800	560	-	-
5023	500	1400	1000	700	-	-
5621	560	1800	1250	900	710	560
5627	560	2250	1600	1120	900	710
6321	630	2500	1800	1250	1000	800
6324	630	2800	2000	1400	1120	900
6327	630	3150	2250	1600	1250	1000
6329	630	3550	2500	1800	1400	1120
7125	710	4000	2800	2000	1600	1250
7127	710	4500	3150	2250	1800	1400
7130	710	5000	3550	2500	2000	1600
7133	710	5600	4000	2800	2250	1800
8030	800	6300	4500	3150	2500	2000
8033	800	7100	5000	3550	2800	2250
8036	800	8000	5600	4000	3150	2500
8040	800	9000	6300	4500	3550	2800
9033	900	10000	7100	5000	4000	3150
9036	900	11200	8000	5600	4500	3550
9040	900	12500	9000	6300	5000	4000
9045	900	14000	10000	7100	5600	4500
1038	1000	16000	11200	8000	6300	5000
1042	1000	18000	12500	9000	7100	5600
1047	1000	20000	14000	10000	8000	6300
1053	1000	22500	16000	11200	9000	7100
1148	1120	25000	18000	12500	10000	8000
1153	1120	28000	20000	14000	11200	9000
1158	1120	31500	22500	-	-	-
1164	1120	35500	-	-	-	-

14. Industry solutions

Excerpt

Year of delivery	Ordering party	Object / Driven equipment	Machine type	Qty.	Power output kW	Rated voltage kV
2004	DMS ZI LILLE SECLIN	Quingdao / China Rolling mill drive	DMMYZ 8044-6Y	7	4,000	3.0
2003	Alstom	Rasselstein /Deutschland Rolling mill drive	DMMYZ 9040-4Y	1	4,000	2.0
2003	Alstom	TKS Bruckhausen / Deutschland Rolling mill drive	DMMYZ 2246-6Y	1	5,000	2.0
2003	Linde AG	Kollsnes / Norwegen Turbocharger compressor drive	DTKFU 1044-4WS EExp IIA T3	1	18,500	11.0
2003	Lungi	LDPE Marun / Iran Piston compressor drive	DTKVY 4931-30WS EExp II T3	1	22,400	11.0
2002	Siemens AG	CISA RCM / Brasilien Coiler drive	DMMYZ 8040-6	2	2,719	3.3
2002	Siemens AG	CISA RCM / Brasilien Stand drive	DMMYZ 1038-6	1	6,000	6.6
2001	Alstom	Corus Staal B.V. / Niederlande Shearing drive	DMMYZ 8027-8	2	3,000	1.35
2001	Alstom	Lesum II / Deutschland Piston compressor drive	DTMYZ 1025-10 EExp II T3	1	3,250	1.65
2000	Linde AG	Luftverdichter Linz / Österreich Air compressor drive	DTKYY 1131-6W	1	12,500	6.0
2000	STN Atlas Marine Electronics	SKY II / Norwegen Propeller motor	DTMYZ 3070-16	2	15,000	2.9
2000	Siemens AG	Pingxiang / China Block drive	DMMYZ 9036-6	1	6,300	1.75
1999	Salzgitter Anlagenbau	LDPE-Projekt BASELL / Frankreich Piston compressor drive	DTKVY 4937-30W EExp II T3	1	23,500	11.0
1999	Alstom / Mannesmann Demag	Nosta / Russland Dual drive	DMMYZ 3067-16	2	5,000	1.575
1997	Salzgitter Anlagenbau	Novy Urengoy / GUS Piston compressor drive	DTKVY 3253-30W EExp II T3	3	11,700	10.0