Three-Phase High-Voltage Asynchronous Motors

140 to 28,000 kW
Three-phase high-voltage asynchronous motor with squirrel cage rotor in use as absorber pump for "Schwarze Pumpe" (Black Pump) power station.
Three-phase high-voltage asynchronous motor with squirrel cage rotor in use as absorber pump for "Schwarze Pumpe" (Black Pump) power station.

Table of contents

1. Summary of supply 6
2. Model designation 8
3. Norms and regulations 9
4. Electrical designs 10
  4.1 Voltage and frequency 10
  4.2 Performance and temperature rise 10
  4.3 Constant speeds 11
  4.4 Variable speeds 11
  4.5 Start-up 14
    4.5.1 Asynchronous motors with squirrel cage rotor 14
    4.5.2 Asynchronous motors with slip ring rotors 15
5. Design description 16
  5.1 Cast construction 16
    (up to shaft centre height 710 mm)
  5.2 Welded construction 17
    (from shaft centre height 800 mm)
  5.3 Stator winding 17
  5.4 Rotor construction 18
    5.4.1 Short-circuit rotor 18
    5.4.2 Slip ring rotor 18
  5.5 Winding connections 18
  5.6 Bearings 20
  5.7 Short-circuit and brush lifting device 21
  5.8 Cooling 22
    5.8.1 Inner air flow 22
    5.8.2 Air-water cooling (IC B A1 W7) 22
    5.8.3 Air-to-air cooling (IC B A1 A1) 23
    5.8.4 Enclosed ventilation (IC 0 A1) 23
6. Explosion-proof motors 24
7. Universal VEMoDUR insulation system 26
8. Inspections 28
9. Documentation 29
10. Shipping, packaging, and installation 30
11. General instructions 31
12. Explosion drawings 32
Three-phase high-voltage asynchronous machines are proven, powerful drives for all branches of industry. They can be employed universally through use of various protection and cooling types. Sachsenwerk offers you the right solution for each application with machines that meet market demands and stand up to the competition. They distinguish themselves through reliability, ease of maintenance, adaptability, modular design, high energy parameters and low noise emissions.

Comprehensive know-how in the factory and constant further development in collaboration with institutes and universities guarantee customer-specific solutions of high quality. For many decades, the high-voltage machines under the VEM trademark have proven themselves in the most varied of uses as drives for pumps, compressors, rotary furnaces and mills, in mining, the chemical and petrochemical industry, steel and rolling mills as well as environmental and energy technology.

All motors are designed in a customer-specific manner to fulfill the special application criteria. The catalogue contains general technical explanations. Individual requirements must be treated separately. The technical data of the basic series can also be requested 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

Three-phase high-voltage asynchronous motors with voltage of 6 kV.
1. Summary of supply

Three-phase high-voltage asynchronous motors with voltage of 6 kV.

- Squirrel cage rotors
- Slip ring rotor

<table>
<thead>
<tr>
<th>Power in kW</th>
<th>22,500</th>
<th>18,000</th>
<th>14,000</th>
<th>11,200</th>
<th>9,000</th>
<th>7,100</th>
<th>6,300</th>
<th>5,600</th>
<th>5,000</th>
<th>4,500</th>
<th>4,000</th>
<th>3,550</th>
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<tbody>
<tr>
<td>DKK 4 6 8 10 12 16</td>
<td></td>
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</table>

Three-phase high-voltage asynchronous motors with voltage of 10 kV.

- Squirrel cage rotors
- Slip ring rotor

<table>
<thead>
<tr>
<th>Power in kW</th>
<th>4,600</th>
<th>4,500</th>
<th>4,000</th>
<th>3,550</th>
</tr>
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<td>DKK 4 6 8 10 12 16</td>
<td></td>
<td></td>
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<td></td>
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- Air-water cooling
- Air-to-air cooling
2. Model designation

The Sachsenwerk model designations consist of letters and numbers.

<table>
<thead>
<tr>
<th>Position</th>
<th>Letters</th>
<th>Position</th>
<th>Numbers</th>
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<th>Numbers/letters</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>E</td>
<td>1-5</td>
<td>D</td>
<td>6-9</td>
<td>10-14 variable</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td></td>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 with 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; IP24)
   - 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-water cooler (IP44; IP54; IP55)
   - S Circulation cooling / forced-air cooling with air-cooler with supplementalventilation unit (IP44; IP54; IP55)
   - M Circulation cooling / forced-air cooling with air-water cooler with supplementalventilation unit (IP44; IP54; IP55)
   - N Circulation cooling / self- 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 supplemental ventilation unit (IP54)

4 and 5 **Design type** (encrypted)
   - Bearing, varying voltage and frequency,
   - Explosion protection, construction, high-load start, etc.

6 and 7 **Centre height** (encrypted)

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

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

12 to 14 **Additional letter for rework stage and special conditions**
   - Letter codes for special winding designs
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<th>Numbers</th>
<th>Numbers/letters</th>
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<tbody>
<tr>
<td>1-5</td>
<td>D K K E R</td>
<td>6 3 2 1 4</td>
<td>WE</td>
</tr>
</tbody>
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   - E = Single-phase AC
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   - A = AC current - asynchronous - generator
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   - B = AC current - asynchronous - slip ring rotor motor with BAV
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   - R = AC current - synchronous - generator without slip rings
   - M = AC current - synchronous - motor with slip rings
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6 and 7. Centre height (encrypted)

8 and 9. Stamping pack length (encrypted)

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. Normen und Vorschriften

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 behavior
  - DIN EN 60034-1 (VDE 0530-1) - IEC 60034-1
- Part 2 Procedure to determine the loss of efficiency...
  - DIN EN 60034-2 (VDE 0530-2) - IEC 60034-2
- 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 Designation for types of construction...
  - DIN EN 60034-7 (VDE 0530-7) - IEC 60034-7
- Part 8 Connection designations and direction of rotation...
  - DIN VDE 0530-8 - IEC 60034-8
- Part 9 Noise limits...
  - DIN EN 60034-9 (VDE 0530-9) - IEC 60034-9
- Part 12 Start-up behaviour of three-phase current motors with squirrel cage rotor...
  - DIN EN 60034-12 (VDE 0530-12) - IEC 60034-12
- 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 18 Functional evaluation of insulation systems...
  - DIN EN 60034-18... (VDE 0530-18...) - IEC 60034-18... multiple parts
  - as well as
  - DIN ISO 10816-... Evaluation of the vibrations of machines through measurements of non-rotating parts... (multiple parts)
  - DIN ISO 8821 "Mechanical vibrations, agreement on the feather key type when balancing shafts and connecting parts"
  - DIN ISO 1940-... Requirements for the balancing quality of rigid rotors... (multiple parts)

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 50016 (VDE 0170/0171 Part 3)
- DIN EN 50019 (VDE 0170/0171 Part 6)
- DIN EN 50021 (VDE 0170/0171 Part 16)

On request, the products can be supplied in accordance with other standards, e.g.: the IEC standards in the co-ordination process as well as special regulations of industry, such as ZLM (additional supply agreements for high-voltage electrical motors in power plants) or the Shell specification.
4. Electrical design

4.1 Voltage and frequency
In the basic design, the motors are dimensioned for the voltage rating 6 kV and the frequency rating 50 Hz.

Voltage and frequency fluctuations during operation are possible in agreement with the stipulations in DIN EN 60034-1, Section 6.3.

Motors for voltage ranges \( \leq 3.3 \text{ kV} \) have higher, motors for voltage ranges \( > 6.6 \text{ kV} \) lower rated outputs with the same construction models.

4.2 Performance and temperature rise
The rated outputs stated in the summary of supply hold for continuous operation (S1) with rated frequency, rated voltage, emplacement altitude \( \leq 1,000 \text{ m} \) above sea level and a cooling air entry temperature of max. 40°C or cooling water entry temperature of 27°C. The maximum effective temperatures correspond to the insulation class B in accordance with DIN EN 60034, measured by the resistance method. Motors can be supplied with a temperature rise limit in accordance with insulation class F.

Fig. 1 Influence of the emplacement altitude and the cooling air entry temperature on the allowable performance
4. Electrical design

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

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

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The rated outputs stated in the summary of supply hold for continuous operation (S1) with rated frequency, rated voltage, emplacement altitude ≤ 1,000 m above sea level and a cooling air entry temperature of max. 40°C or cooling water entry temperature of max. 27°C. The maximum effective temperatures correspond to the insulation class B in accordance with DIN EN 60034, measured by the resistance method. Motors can be supplied with a temperature rise limit in accordance with insulation class F.

Deviations from the rated values of the cooling air temperature and the emplacement altitude produce a percentage change in the maximum possible performance corresponding to Fig. 1.

4.3 Constant speeds
The rated speeds listed in the summary of supply apply for operation at rated voltage, rated frequency, and rated power (tolerances according to DIN EN 60034-1).

The machines are spun at 1.2 times the no-load speed. This applies for 50-Hz machines and also for other frequencies. For higher spin speeds, please contact us.

4.4 Variable speeds/speed regulator
Slip ring rotor motors with converter power supply in the rotor circuit
The current circuit of the slip ring rotor motors uses a converter that controls speed through a voltage boost with low loss. The frequency of the boost is adapted to the rotor frequency of the asynchronous machine (subsynchronous converter cascade system).

Because of the upper harmonic waves of the A.C.-D.C. converter, operation of a subsynchronous converter cascade system requires a reduction of the rated power of the motors of about 5%. It should be noted that, at reduced speed of the drive motor, heat removal with self-ventilation fails. With a reduction of speed, therefore, the torque must be reduced in accordance with Fig. 2.

Slip ring rotor motors above 2 MW must be reduced more strongly in their power output due to the current displacement in the rotor winding at speeds under 70 % n_n.

The advantages of speed control with subsynchronous converter cascade system are:
- low losses, since the slip power is fed back into the main power network
- low cost, since the necessary converter power at a small regulating range (e.g. 0.7 n_n to 1.0 n_n) is less than with stator circuit feed.
- speeds that are relatively independent of load compared to speed control with slipping resistances in the rotor circuit (see Fig. 3.)

Fig. 1 Influence of the emplacement altitude and the cooling air entry temperature on the allowable performance

Fig. 2 Performance and moment reduction when speed is set using a subsynchronous converter cascade system
Squirrel cage motors with converter

Either a current- or voltage-impressing frequency converter is used in the stator circuit of the squirrel cage motors. VEM motors are specially adapted for the respective converter operation and drive task. This means, depending on the converter type and the specific demands of the respective converter, the insulation is adapted and the rated power optimised. The mechanical design largely corresponds to that of the standard machines.

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

The windings of the machines are preferably made as pulled coils or in special cases as transposed conductor windings and dipped in the VPI method. Through an exceptionally high initial quality of the winding wires used, the very regular winding structure compared to round-wire windings and the related favourable voltage distribution inside the coils, and the advantages of the VPI method in soaking the winding head, very high security is achieved against the possible voltage peaks possible in converter operation.

The operation of the motors on frequency converters results in a higher noise level than with sinusoidal main power networks.

The standard values for this are:

<table>
<thead>
<tr>
<th>Converter type</th>
<th>Increase in the acoustic pressure level $L_{PA}$ in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-converter</td>
<td>1 - 4</td>
</tr>
<tr>
<td>U-converter</td>
<td>1 - 15</td>
</tr>
</tbody>
</table>

In the case of converters, the increase in the acoustic pressure level depends on:
- pulse frequency
- pulse pattern
- output filter

![Fig. 3 Voltage regulation characteristic lines of asynchronous motors with slip ring rotors](image)

a) with subsynchronous converter cascade system

b) with slipping resistance
Squirrel cage motors with converter

Either a current- or voltage-impressing frequency converter is used in the stator circuit of the squirrel cage motors. VEM motors are specially adapted for the respective converter operation and drive task. This means, depending on the converter type and the specific demands of the respective converter, the insulation is adapted and the rated power optimised. The mechanical design largely corresponds to that of the standard machines. In the case of converter-fed machines, the converter type must be stated in the inquiry.

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The advantages of controlling the speed of squirrel cage motors using frequency converters are:
- Optimal adaptation of the motor’s speed and torque to the technological requirements of the work machine
- Optimal efficiency over a very broad range of power and speed
- Power feed from the main power network with very good power factor (U-converter)
- Energy return feed into the main power network is achievable
- Good synchronisation in the case of multiple motor drives
- High speed constancy with changing load
- Large speed range with minimal losses possible (see Fig. 4)

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- Pulse frequency
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- Output filter

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In all converter-fed motors, a bearing is insulated to avoid bearing currents if feed takes place through I-converters or U-converters with an output voltage on the motor side up to 690 V. For motors driven by medium voltage converters, two insulated bearings and an earthing brush are used if there are no other instructions.

Motors for work machines with relatively constant torques, e.g. drives for mills, compressors and rolling mills, are frequently equipped with an external air unit.
4.5 Start-up

4.5.1 Asynchronous motors with squirrel cage rotor

Normal start-up

All services specified in the summary of supply allow direct start-up on the main power network. This simple start-up procedure should always be used when the main power network conditions or the machines to be driven allow it. The size of the machines is determined by:

- the level of the rated power
- the lost energy to be stored in the motor during run-up.

This corresponds to the kinetic energy needed for acceleration of the work machine, motor rotor and additional masses.

The motor types listed in the summary of supply are dimensioned for normal start-up processes. You can accelerate machines with constant, quadratic or similar load moment curves (see Fig. 5) up to the rated speed. A ratio of the maximum moment of the machine to the nominal moment of the motor of 0.9 at quadratic load moment is assumed. For motors with power > 7 MW, a throttled start-up is used. Here, the voltage drop in the main power network must not exceed a maximum of 10%.

If there are smaller load moments on the motor during start-up, higher voltage breakthroughs are also possible in the main power network. The motor torque and the motor current drop due to saturation more strongly than the squared ratio of main power network voltage to rated voltage.

For example:

$$M_{70\%} = \left( \frac{M_{100\%}}{U_{100\%}} \right)^2 \cdot A \cdot M_{100\%}$$

$$A = \text{correction factor, whereby ist } A < 1$$

The time period for the start-up is determined by the total moment of inertia, the rated speed and the acceleration torque (motor torque - passive moment of the machine).

The result is:

$$t_s = \frac{J_{\text{ges}} \cdot n_N}{M_{\text{Bereich}}} \cdot 0.105$$

$$t_s = \text{start-up time (s)}$$
$$J_{\text{tot}} = \text{total moment of inertia (kgm}^2\text{)}$$
$$n_N = \text{rated speed (min}^{-1}\text{)}$$
$$M_{\text{Acc.}} = \text{acceleration torque (Nm)}$$

![Fig. 5 Torques and start-up current of a 2-pole motor during start-up](image1)

![Fig. 6 Torques with various short-circuit rotor designs](image2)
4.5 Start-up

4.5.1 Asynchronous motors with squirrel cage rotor

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If there are smaller load moments on the motor during start-up, higher voltage breakthroughs are also possible in the main power network. The motor torque and the motor current drop due to saturation more strongly than the squared ratio of main power network voltage to rated voltage.

For example:

\[
M_{\text{max}} = \left(\frac{U_{\text{min}}}{U_{\text{nom}}}\right)^2 \cdot A \cdot M_{\text{nom}}
\]

\[A = \text{correction factor, whereby } A < 1\]

The time period for the start-up is determined by the total moment of inertia, the rated speed and the acceleration torque (motor torque - passive moment of the machine).

The result is:

\[t_s = \frac{J_{\text{tot}}}{\frac{\text{rotation}}{\text{speed}}^2} \cdot 0.105\]

\[t_s = \text{start-up time (s)}\]

\[J_{\text{tot}} = \text{total moment of inertia (kgm}^2\text{)}\]

\[n_N = \text{rated speed (min}^{-1}\text{)}\]

\[M_{\text{Acc.}} = \text{acceleration torque (Nm)}\]

For a first estimated calculation, it is enough to graphically estimate the acceleration torque. Exact calculations are performed with the help of iterative procedures.

The switch frequency in the basic design is up to 1000 switches per year if nothing else is agreed on.

The motors with squirrel cage rotors of shaft centre height 355 mm to 800 mm are suitable for automatic mains reversing switchings without residual voltage limitations. The purchaser should indicate these.

High-load start

If the drive tasks place increased demands on the direct start-up of motors with squirrel cage rotors, such as high moments of inertia or high load moments with increased voltage breakthrough, the motor must be specially designed. Larger torques can be achieved through the use of different copper base alloys or rod shapes in the rotor.

Start-up via starting transformers

This start-up procedure is used if low start-up current is required due to weak main power networks. It must be ensured thereby that the passive moment of the machine has low values (throttling) at the time of the start-up.

For example:

\[M_{70\%} = \frac{M_{\text{nom}}}{100\%} \cdot 0.705\]

\[M_{70\%} = \text{torque (motor torque - passive moment of the machine)}\]

This start-up procedure is used if low start-up current is required due to weak main power networks. It must be ensured thereby that the passive moment of the machine has low values (throttling) at the time of the start-up.

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\[M_{70\%} = \text{torque (motor torque - passive moment of the machine)}\]

4.5.2 Asynchronous motors with slip ring rotors

They are designed for difficult start-up conditions. With the help of resistances in the rotor circuit, both the motor current and the motor torque can be set in broad areas during start-up. Through external discrete supplementary resistance, the motor torque can be graduated as in Fig. 7.

If a constant motor current and torque are needed over the entire start-up process, continuously variable liquid starters should be used.

Through regulated electrode drives in the liquid starter, the current and torque can be set within narrow limits so that long start-up times are possible even with high motor power.

In the case of starter slip ring rotors, it is possible after successful run-up to short circuit the rotor circuit and lift the brushes from the slip rings with the help of an automatic brush lifting device (option). Mains reversing switchings and interruptions must be avoided with slip ring rotors.
5. Design description

5.1 Cast construction (up to shaft centre height 710 mm)
The outstanding characteristic of the VEM motors is their cast construction up to a shaft centre height 710 mm. Through this robust design, they are predestined for use under the most varied of operating and environmental conditions.
The motor series up to a shaft centre height of 710 mm is designed according to the modular concept.
The design consists of the following parts: A cast housing to receive the stator stamping packs, two pot end shields made of grey cast iron and two bearing heads. These construction elements are screwed together axially. A continuous centring of the assemblies one by one makes an air gap check unnecessary even after disassembly. Radially arrayed guides ensure an exact tangential positioning of the end shields with the stator housing after disassembly.
The stator stamping pack is fixed in the housing via a press fit and then spooled.
In the construction type IM V1, the drive-side pot end shield possesses a caste flange for setting up the motor.

Air-to-air-cooled asynchronous machine with cast housing and slip ring rotors
5. Design description

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The outstanding characteristic of the VEM motors is their cast construction up to a shaft centre height 710 mm. Through this robust design, they are predestined for use under the most varied of operating and environmental conditions.
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The stator stamping pack is fixed in the housing via a press fit and then spooled.
In the construction type IM V1, the drive-side pot end shield possesses a cast flange for setting up the motor.

5.2 Welded construction
(from shaft centre height 800 mm)
The stator housing consists of a welded construction. The end shields are designed as discs and receive the bearing heads.
The stamping pack is put together out of insulated dynamo sheet round plates or overlapped dynamo sheet segments and axially tensioned over end plates with press pins. The stator pack is shrunk in the stator housing. A press spring is used to receive the short-circuit moment. A continuous centring of the assemblies one by one makes an air gap check unnecessary even after disassembly.

5.3 Stator winding
The three-phase double-layer winding lies in the open grooves of the stamping pack. Depending on the machine size, it is implemented as a whole pulled coil or transposed conductor winding.
Flat copper wire, insulated with mica foil, is used for the entire pulled coils.
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 low adhesive mica-fibreglass tape. To avoid corona discharges, installed in the slot part is a low impedance and in the slot exit a high impedance mica protective cover.

The completely insulated conductor packages are fixed in the slots using slot connectors made of glass fabric and epoxy resin. The switch connections are hard-soldered at the whole pulled coil winding; in the case of transposed conductor windings, the staff connections are made through TIG-inert gas shielded arc welding.
The stators with the installed whole pulled coils up to a diameter of 4,500 mm are completely dipped according to the VPI 155 process.

The completely wound stator stamping pack with housing is thereby impregnated in an epoxy-resin bath (insulating system VEMoDUR-VPI-155), first under vacuum and then under pressure. The subsequent heat treatment hardens the resin.
A cavity-free winding insulation and a bonded stamping pack are thus guaranteed.
The winding and the slot wedges are likewise fixed with the epoxy resin in the stamping pack. The winding heads are able to take up large deformation forces, which can be caused by load shocks and mains switch-ons.
5.4 Rotor construction
Depending on machine size, the rotor construction is either a solid shaft or welded ribbed shaft. The rotor stamping pack consists of dynamo sheet round plates or overlapped layered dynamo sheet segments. The stamping pack is tensioned axially with press pins. Stamping packs consisting of round plates are shrunk onto the shaft. Stamping packs made up of segments are laminated onto dovetail-shaped strips of the ribbed shaft. Rotors with ribbed shafts have a feather key to receive the short-circuit moment.

5.4.1 Short-circuit rotor
The rotor rods made of copper or copper base alloys are inductively soldered axially with the protruding short-circuit disks. The special shape of the short circuit disc and the rotor rods ensures a high soldering quality in the case of vertical soldering and a radial securing of the short circuit rods. The outer contour of the short circuit discs is worked on only after the soldering is complete in order to achieve an optimal pre-balancing condition.
If mechanically required, 2-pole rotors are also equipped with non-magnetic shrunk-on rings or the connection of the short circuit rod with the short circuit disc is made through a special wedge fastening.

5.4.2 Slip ring rotor
The rotor winding consists of a two-layer bar winding. The insulation system VEMoDUR-VPI-155 ensures a high mechanical and electrical safety of the winding.
The winding heads are cushioned against centrifugal forces by means of glass bindings. The winding ends are brought to the slip ring pins. The slip rings are cantilevered on a cast iron hub and insulated from each other axially with porcelain insulators. The slip rings themselves consist of stainless steel. A spiral-shaped slotting of the running surface increases the cooling effect; the slots simultaneously serve to keep the brush running surface clean.

Short-circuit rotors for a radially ventilated asynchronous machine
Slip ring rotor
5.4 Rotor construction
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5.5 Winding connections
Connecting box for stators
The connecting boxes are made in protection class IP55. The divided connecting box is welded and possesses a predetermined breaking point (pressure relief) and an earthling terminal in the bottom part. The bottom part is screwed to the connecting flange of the housing. Bore holes in the bottom part of the box receive the three duct insulators. In them, the duct bolts for the lines are attached and secured against rotation. The wires leading to the stator winding are lightly soldered into the duct bolts. The cable leading to the main power network is clamped onto the duct bolts (U, V, W).

If mechanically required, 2-pole rotors are also equipped with non-magnetic shrunk-on rings or the connection of the short circuit rod with the short circuit disc is made through a special wedge fastening.

Depending on the nominal current and possible short-circuiting power, the high-voltage boxes contain three duct bolts with ceramic or short-circuit-resistant cast-resin insulators.

<table>
<thead>
<tr>
<th>Form</th>
<th>Rated current (A)</th>
<th>Connecting pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>≤ 250</td>
<td>M 12</td>
</tr>
<tr>
<td>A2</td>
<td>≤ 250</td>
<td>M 16</td>
</tr>
<tr>
<td>B1</td>
<td>≤ 250</td>
<td>M 12</td>
</tr>
<tr>
<td>B2</td>
<td>≤ 400</td>
<td>M 16</td>
</tr>
<tr>
<td>C1</td>
<td>≤ 250</td>
<td>M 12</td>
</tr>
<tr>
<td>C2</td>
<td>≤ 400</td>
<td>M 16</td>
</tr>
<tr>
<td>D1</td>
<td>≤ 250</td>
<td>M 12</td>
</tr>
<tr>
<td>D2</td>
<td>≤ 400</td>
<td>M 16</td>
</tr>
</tbody>
</table>

The cast-resin insulators can handle short-circuit current up to 50 kA for 0.2 s.

Connecting box for rotor connection (3 kV)
The rotor connecting box is welded and, like the stator connection, designed for protection rating IP 55. The cables on the power network side are carried on contact rails. The contact rails are connected to the brush yoke through cables that are very well insulated thermally and electrically.
5.6 Bearings

Anti-friction bearing

The motor bearings are attached according to the principle that the locating bearings are on the drive side (D-end) and the floating bearings on the non-drive side (ND-end). The standard design is with one deep groove ball bearing that is pre-tensioned using compression springs.

For machines from shaft centre height 710 mm, the D-end has a double bearing (locating bearing) consisting of a cylinder roller bearing and deep groove ball bearing; the ND-end only receives a cylinder roller bearing.

The locating bearing takes over any axial forces that may arise. The computed nominal life (Lh10) of the bearings = 50,000 hours.

Designs with special bearings to take up higher radial and axial forces are possible on request.

In the standard design, the bearings are sealed inside and outside with gap seals. They are maintenance-free and protect against penetration of dust and spray water.

For special conditions of use, designs are possible with labyrinth or double labyrinth seals.

The bearings are first greased in the factory with lithium-base-saponified grease in accordance with DIN 51825.

To avoid over-greasing of the bearings, all bearings are equipped with grease quantity control. In the bearing housing, old grease is precipitated via grease baffle plates and grease thrower rings. The used grease is removed through a grease slide valve locked in the outer bearing cover.

To re-grease the bearings, easily accessible lube nipples or lube pipes are planned.

Re-greasing takes place with the motor running. The corresponding re-greasing deadlines and quantities are specified on an instruction plate beside the lube nipple.

From shaft centre height 500, all motors receive an insulated bearing on the ND-end to avoid harmful bearing current (option: two insulated bearings with earthing brush). On request, even the smaller construction sizes can be designed with an insulated bearing.

For the construction type V1, the following bearing designs are used:

<table>
<thead>
<tr>
<th>Bearing Group</th>
<th>Design Type</th>
<th>Top Bearing</th>
<th>Bottom Bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH 450</td>
<td>Single bearing</td>
<td>Cylinder roller bearings</td>
<td>Angular contact ball bearing</td>
</tr>
<tr>
<td>AH 500/560</td>
<td>Double bearing</td>
<td>Diagonal cylinder roller bearing</td>
<td>Cylinder roller bearings</td>
</tr>
<tr>
<td>AH 710</td>
<td></td>
<td>Self-aligning roller thrust bearing/oil pan</td>
<td>Cylinder roller bearings</td>
</tr>
</tbody>
</table>

Bearing group mounted on the bearing end shield
5.6 Bearings

**Anti-friction bearing**

The motor bearings are attached according to the principle that the locating bearings are on the drive side (D-end) and the floating bearings on the non-drive side (ND-end).

The standard design is with one deep groove ball bearing that is pre-tensioned using compression springs. For machines from shaft centre height 710 mm, the D-end has a double bearing (locating bearing) consisting of a cylinder roller bearing and deep groove ball bearing; the ND-end only receives a cylinder roller bearing.

The locating bearing takes over any axial forces that may arise. The computed nominal life (Lh10) of the bearings = 50,000 hours.

Designs with special bearings to take up higher radial and axial forces are possible on request.

In the standard design, the bearings are sealed inside and outside with gap seals. They are maintenance-free and protect against penetration of dust and spray water. For special conditions of use, designs are possible with labyrinth seals.

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To re-grease the bearings, easily accessible lube nipples or lube pipes are planned. Re-greasing takes place with the motor running. The corresponding re-greasing deadlines and quantities are specified on an instruction plate beside the lube nipple.

From shaft centre height 500, all motors receive an insulated bearing on the ND-end to avoid harmful bearing current (option: two insulated bearings with earthing brush). On request, even the smaller construction sizes can be designed with an insulated bearing.

The bearings are first greased in the factory with lithium-barium or double labyrinth seals.

For special conditions of use, designs are possible with labyrinth seals.

**Plain bearing**

The plain bearings are designed as centre-flange or side-flange bearings and screwed on to the centring of the end shield. The bearings have a horizontally divided housing, a divided bearing shell poured out with bearing metal, a lube ring as well as various seals. The protection class of the bearings in their basic design is IP44.

Higher protection classes (IP54) are achieved through additional seals.

The plain bearings are normally designed as floating bearings and do not absorb any axial forces.

Depending on the demands, they can be supplied in the most varied of designs, among others with ring oil lubrication, flood lubrication, water cooling, insulated as well as locating or floating bearings.

If a ring oil lubrication is not sufficient to remove the heat, a plain bearing is planned at the factory for flood lubrication. In this case, an oil ring is also planned to guarantee the necessary oil supply to the bearing up to standstill of the motor shaft in case flushing oil is lost. The necessary monitoring should be planned at the plant to be able to shut the motor off immediately.

The flushing equipment required for this is not contained in the VEM scope of supply. But it can be offered, if requested.

At low speeds, a hydrostatic device can be required. This can be supplied with the motor.

Motors of construction type IM V1 have a combined pressure and locating bearing on top. Below, they are equipped with a guide bearing. If the customer requests, journal and guide bearings can be arrayed below as well as a second guide bearing above.

### Table: Bearing Designs

<table>
<thead>
<tr>
<th>AH</th>
<th>Bearing Design</th>
<th>Top:</th>
<th>Bottom:</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>Single bearing</td>
<td>cylinder roller bearings</td>
<td>angular contact ball bearing</td>
</tr>
<tr>
<td>500/560</td>
<td>Double bearing</td>
<td>Diagonal cylinder roller bearing</td>
<td>cylinder roller bearings</td>
</tr>
<tr>
<td>710</td>
<td>Top: self-aligning roller thrust bearing/oil pan</td>
<td>Bottom: cylinder roller bearings</td>
<td></td>
</tr>
</tbody>
</table>

Motors of construction type IM V1 have a combined pressure and locating bearing on top. Below, they are equipped with a guide bearing. If the customer requests, journal and guide bearings can be arrayed below as well as a second guide bearing above.

5.7 Short-circuit and brush lifting device

Slip ring rotor motors from shaft centre height 400 mm can be equipped with a short-circuit and brush lifting device. A short-circuit and brush lifting device serves to operate a slip ring rotor motor after successful run-up as a short-circuit rotor motor.

In the case of a motor with short-circuit and brush lifting device, the winding ends of the rotor winding are brought to a special slip ring, which possesses a brass segment on every phase. This brass segment is short circuited over a short circuit hub, which is arrayed axially to be shiftable on the motor shaft and equipped with spring-loaded contact pieces. The brush yoke possesses brush holders that can be lifted via levers from the slip ring. The short-circuit and brush lifting device is driven by a worm gear motor attached to the side of the motor. Two inductive sensors supply the signals for the control, to be arranged externally, of the short-circuit and brush lifting device. The slip rings are not grooved for short-circuit-and-brush-lifting-device motors.
5.8 Cooling

5.8.1 Inner air flow
A fan impeller dependent on the direction of rotation is located on the motor shaft on the D-end. For 2-pole motors designed as axial fans, multi-pole motors as radial fans, the heated air on the D-end is pressed through the upper opening in the bearing end shield.

On the N-end, cold air streams from the top into the bearing end shield. There it is divided into partial airflows that flood the stator back or stream through axial cooling ducts in the rotor and in the stator as well as through the air gap.

Higher-pole motors from shaft centre height 630 mm are radially ventilated. The air thereby flows through arrayed cooling ducts in the rotor and in the stator. Depending on the size of the motor, the radial ventilation is designed as Z ventilation or two-sided radial ventilation.

When radial fans that are independent of the direction of rotation are used, increased noise emissions and lower efficiencies are observed.

5.8.2 Air-water cooling (IC 8 A1 W7)
In air-water cooling, the motor exhaust flows through a hood, which is designed as a welded structure. The air-water heat exchanger is arrayed in the hood as a plug-in element. This is designed as a lamellar tube heat exchanger. The selection of material for cooling pipes and water chambers is oriented on the cooling water quality. Double-pipe coolers can be used for special applications. The inner cooling circuit is separated from the surroundings through sealing measures according to the motor protection class.

The motors are thus suitable for set-up in media where the air for cooling is not sufficiently clean or the machines have to be protected against external influences, such as weather or atmosphere.

Upon request, redundant cooler designs as well as water-related rules and monitoring of the air and water can be implemented. A leakage alarm can be provided for cooler monitoring.

Likewise, noise protective measures can be integrated into the circulating-air housing.

In air-water cooling, the inner cooling circuit can also be driven through a separate ventilation unit in the cooler hood. As a result, the motor corresponds to the cooling type IC 8 A6 W7 and is suitable for variable speeds.
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5.8.3 Air-to-air cooling (IC 8 A1 A1)
In air-to-air cooling, the motor exhaust flows through a hood, which is designed as a welded structure. In this hood are aluminium tubes whose ends are rolled into the end faces of the hood. This structure forms the air-to-air heat exchanger. The motor exhaust flows around the aluminium tubes and is cooled down through the secondary air flow within the tubes. The secondary air flow is thereby fed through a fan on the N-end on the motor shaft. The secondary fan is covered by a hood with intake. The inner cooling circuit is separated from the surroundings through sealing measures according to the motor protection class. In air-to-air cooling, the inner cooling circuit and the secondary air flow can be driven through separate ventilation units. As a result, the motor corresponds to the cooling type IC 8 A6 A6 and is suitable for variable speeds.

5.8.4 Enclosed ventilation (IC 0 A1)
With enclosed ventilation, the cooling air is taken in over a hood. The motor exhaust, cut off from the cooling air, is blown out through the same hood on the D-end. The hood is designed as a welded structure. It serves to separate the air flows between warm and cold air. Enclosed ventilation can be used in cases where the temperature of the surroundings is suitable for machine cooling. Through the use of a separate ventilation unit for the cooling-air stream, the motor is of the cooling type IC 0 A6 and is thus suitable for variable speeds.
Special stipulations and ordinances apply for the set-up of motors in explosion-hazardous areas in which explosive atmospheres can arise in threatening quantities. The areas are thereby divided into zones (EN 60079-10; DIN VDE 0165 part 101), and the production tools, i.e. also die electric machines, are divided into device categories or ignition protection types (EN and IEC standards, ATEX guidelines). All European manufactures should observe thereby that the ATEX guidelines are legally binding from 1 July 2003.

Depending on the conditions at the location of use, Sachsenwerk motors are delivered with the types of ignition protection:
- increased safety "e" (in accordance with DIN EN 50014 / DIN EN 50019 and IEC 60079-7)
- pressurisation "p" (in accordance with DIN 4102 EN 50014 / DIN EN 50016)
- sparkless in normal operation "n" (in accordance with DIN EN 50014 / DIN EN 50021).

6. Explosion-proof motors

Asynchronous motor with squirrel cage rotor, compressor drive 2,852 kW

Function model for insulation system test Exe
6. Explosion-proof motors

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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 is to be conducted and measures to minimise risk adopted, if applicable.

For high-voltage machines with rated voltage \( U_N = 6 \, \text{kV} \), 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.
7. Universal VEMoDUR insulation system

The operating reliability of electrical machines is decisively determined by the quality of their winding insulation. The insulation technology at Sachsenwerk has always been characterised by technical solutions that, in their quality parameters, meet the international standard and thus ensure the operators products with high reliability and long useful lives.

The VPI technique (vacuum pressure impregnation) is used for high-voltage machines. The related insulation system VEMoDUR-VPI-155 was developed at Sachsenwerk and 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.

To guarantee the quality of the insulation system, all components are subjected to a receipt inspection in accordance with DIN 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) are guaranteed for all machines with great security (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) (extract).

<table>
<thead>
<tr>
<th>Rated voltage $U_N$ in kV</th>
<th>Rated surge voltage (peak value) in kV Shaft 1.2/50 $(4U_N + 5 \text{kV})$</th>
<th>Mains frequency testing voltage (effective value) in kV $(2U_N + 1 \text{kV})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>29</td>
<td>13</td>
</tr>
<tr>
<td>6,6</td>
<td>31</td>
<td>14,2</td>
</tr>
<tr>
<td>10</td>
<td>45</td>
<td>21</td>
</tr>
<tr>
<td>11</td>
<td>49</td>
<td>23</td>
</tr>
<tr>
<td>13,8</td>
<td>60</td>
<td>28,6</td>
</tr>
<tr>
<td>15</td>
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<td>31</td>
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This system contains the following listed main components for the stator windings:

- Winding insulation: mica foil bands
- Main insulation: mica-fibreglass bands (groove and core chuck) (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 IEC 60034-18-31.

To guarantee the quality of the insulation system, all components are subjected to a receipt inspection in accordance with DIN ISO 9001.

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- viscosity of the resin
- impregnation and curing temperature
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<table>
<thead>
<tr>
<th>Rated voltage $U_n$ in kV</th>
<th>Rated surge voltage (peak value) in kV ($2U_n + 5$ kV)</th>
<th>Mains frequency testing voltage (effective value) in kV ($2U_n + 1$ kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>29</td>
<td>13</td>
</tr>
<tr>
<td>6.6</td>
<td>31</td>
<td>14.2</td>
</tr>
<tr>
<td>10</td>
<td>45</td>
<td>21</td>
</tr>
<tr>
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<td>23</td>
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</tr>
<tr>
<td>15</td>
<td>65</td>
<td>31</td>
</tr>
</tbody>
</table>

The insulation system is marked by a high climate resistance, i.e., the winding is not sensitive to moist and aggressive atmospheres.

This insulation system is the standard design.

Upon customer request, Sachsenwerk is also able to supply special designs with increased rated surge voltages.

Example: $U_n = 11$ kV

Main insulation: 80 kV
Winding insulation: 60 kV

Within the framework of internal quality inspection in accordance with DIN VDE, electrical intermediate and final checks of the insulation strength are performed and, upon customer request, also 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 EEEx in accordance with DIN EN 50019 as well as Exe as per IEC 60079-7.
8. 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, brush type and dimensions for slip ring rotor machines)
- 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
- Transmission for slip ring rotor machines
- Setting of the magnetic centre for plain bearings
- Check of direction of rotation
- Idle characteristics line for determining magnetic and frictional losses, calculation check of efficiency, if required
- Vibration severity measurement
- Determination of the SPM level with corresponding feature
- Short circuit characteristics line with blocked rotor for control of the start-up current
- Winding check (high voltage test)
- Functional capability of the accessories

**Type inspections**

If the customer wishes, additional inspections can be performed under 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
- Noise measurement at idle
- Run-up to the determined moment
- Remaining voltage when the idling machine is shut off
- Inertia from the retardation test
- Thermal test with rating or substitute tests
- Thermal time constants, load limit determination
- Operating characteristics curves $\eta = f(P_{el}), \cos \varphi = f(P_{el}), P_{\text{mech}} = f(P_{el}) s = f(P_{el}), I = f(P_{el})$
- Measurement of coolant quantity
- Determination of breakdown torque
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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, brush type and dimensions for slip ring rotor machines)
- 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
- Transmission for slip ring rotor machines
- Setting of the magnetic centre for plain bearings
- Check of direction of rotation
- Idle characteristics line for determining magnetic and frictional losses, calculation check of efficiency, if required
- Vibration severity measurement
- Determination of the SPM level with corresponding feature
- Short circuit characteristics line with blocked rotor for control of the start-up current
- Winding check (high voltage test)
- Functional capability of the accessories

Type inspections
If the customer wishes, additional inspections can be performed under 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
- Noise measurement at idle
- Run-up to the determined moment
- Remaining voltage when the idling machine is shut off
- Inertia from the retardation test
- Thermal test with rating or substitute tests
- Thermal time constants, load limit determination
- Operating characteristics curves $\eta = f(P_{el}), \cos \varphi = f(P_{el})$
- $P_{mech} = f(P_{el}), s = f(P_{el}), I = f(P_{el})$
- Measurement of coolant quantity
- Determination of breakdown torque

9. Documentation

Unless otherwise agreed, the documentation “Operation and Service Manual” contains the following documents:
- Safety instructions
- EC manufacturer’s declaration
- Description / technical data
- Measurement picture of motor
- Measurement picture of cable connection
- 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)

Documentation in addition to this must be contractually agreed.

The documentation is provided in two copies when the product is delivered. It is available in German, English, French, Russian and Spanish. VEM charges for costs of additional copies, additional documentation, and translation into other languages.
The type of packaging is determined at the time of contract according to the transportation and storage conditions named in the order while taking into account the design of the machines. Sachsenwerk is able to offer special packaging and ensure shipping and installation of motors even for the most distant of regions.

The machines are shipped either completely assembled or in a disassembled condition depending on the size and contractual agreements.

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

If VEM is not entrusted with the installation and commissioning of the machine, its liability and warranty are excluded unless the buyer can furnish proof in an appropriate form of correct set-up corresponding to the VEM Operation and Service Manual (log/Logbook Section 9, VEM Operation and Service Manual).

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.
10. Shipping, packaging, installation

The type of packaging is determined at the time of contract according to the transportation and storage conditions named in the order while taking into account the design of the machines. Sachsenwerk is able to offer special packaging and ensure shipping and installation of motors even for the most distant of regions.

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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.

11. 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 12944/31-8 DIN 55928 Part 8+9 and applicable standards.
- The machine’s direction of rotation is right, when looking at the drive end (DE). The terminal 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 end (DE).
- 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 of VEM Sachsenwerk GmbH.
- Vibration monitoring is without evaluation device.
- VEM requires the use of an insulated coupling.
12. Explosion drawings
12. Explosion drawings

Three-phase high-voltage asynchronous motor with slip ring rotor, air-to-air cooled, cast housing

1. Housing
2. End shield
3. Cooler
4. External fan housing
5. Rotor with winding
6. Bearing housing with external bearing cover and grease slide valve
7. Anti-friction bearings
8. Inner bearing cover
9. Internal fan
10. Fan hub
11. Balancing ring
12. Slip ring body
13. Stator stamping pack with winding
14. Air guide plate
15. Sealing ring
16. Cover
17. External fan
18. Fan hub for external fan
19. Air guide plate
20. Intake screen
21. Cable connection box (stator)
22. Cable connection box (rotor)
23. Anti-condensation heater
Three-phase high-voltage asynchronous motor with squirrel cage rotor, air-water-cooled, welded housing

1. Housing
2. End shield
3. Cooler
4. Rotor with winding
5. Stator stamping pack with winding
6. Air guide plate
7. Bearing housing with grease slide valve
8. Inner bearing cover
9. External bearing cover
10. Anti-friction bearings
11. Bearing bush
12. Fan
13. Cover
14. Cable connection box
15. Anti-condensation heater