ELECTRIC DRIVES
FOR EVERY DEMAND

Catalog

Slow Turning Shaft Generators

Content

0 Abbreviations

EE	electrical excited
PM	permanent magnet excitation
SH	Shaft Height / Frame Size
SG	Shaft Generator

1 Introduction

Synchronous machines have always been an important part of the product range of VEM Sachsenwerk GmbH. Decades of VEM experience in the manufacture of high and low voltage machines combined with modern knowledge in

- electromagnetic and mechanical design
- mastery of high-voltage insulation technology
- innovative cooling design
- application of digital control technology and
- rational cost-efficient production methods

have been incorporated into the new series of low-speed three-phase shaft generators. The design and layout of the generator series aimed at ensuring the following characteristics, such as

- High Efficiency
- Durability
- Low installation and commissioning effort
- Maintainability and
- Low noise emissions.

The synchronous machines of this series are manufactured at VEM Sachsenwerk GmbH in Dresden and shipped to customers all over the world. The field of application of these machines is the direct electromagnetic energy conversion - without additional intermediate gear - in the shaft train of ocean-going vessels.



Shaft generators are operated either on a passive rectifier bridge to charge the DC link capacitor of an active frequency converter (AFC) connected to the ship's electrical system in order to feed electrical energy into it. This mode of operation is usually referred to as Power Take Off (PTO) operation.

On the other hand, a shaft generator can be connected directly to an AFC. Thus energy can also be taken from the ship's mains as required and applied to the shaft as mechanical energy in addition to that of the main engine. In this case, the shaft generator operates in motor mode, Power Take In (PTI). In addition, the shaft generators connected to the ship's electrical system can also support Power Take Home (PTH) operation, sailing a damaged ship towards a port as quickly as possible.

The areas of application are:

- Continuous power supply in mains parallel operation with the main engine
- Covering required energy peaks in the ship grid
- Emergency power supply
- Peak load operation
- Ship auxiliary drive

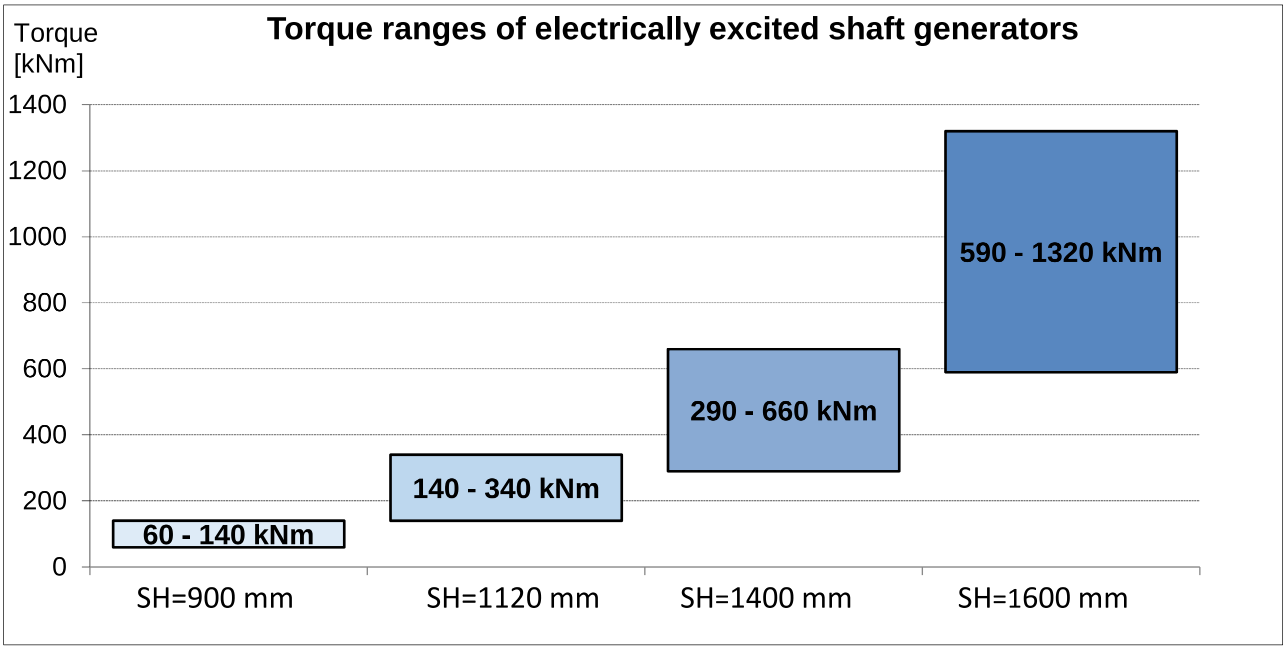
2 Delivery overview

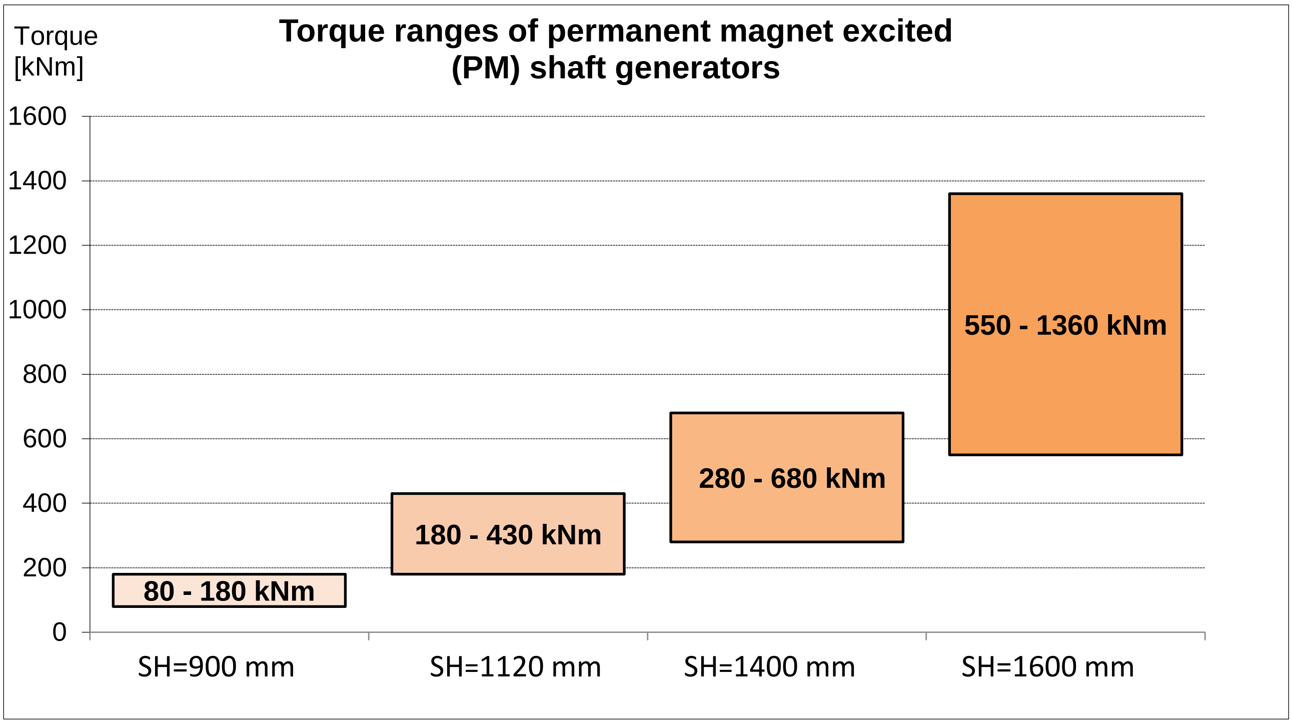
2.1 General

The new series of slow turning three-phase shaft generators is available both as electrically excited synchronous machines (EESG) in salient-pole design or as permanent magnet excited synchronous machines (PMSG) with shaft heights (SH) of 900 mm, 1120 mm, 1400 mm and 1600 mm. The EESG are designed as 16-pole machines, the PMSG as 20- to 36-pole machines.

2.2 Basic version

Voltage:	400 V - 690 V, 3.3 kV - 4.1 kV, 6.6 kV
Speed:	30 rpm - 150 rpm
Power factor cos φ:	(-) 0,94…(+) 0,94
Thermal class:	155 (F), utilization according to 155 (F) or 130 (B)

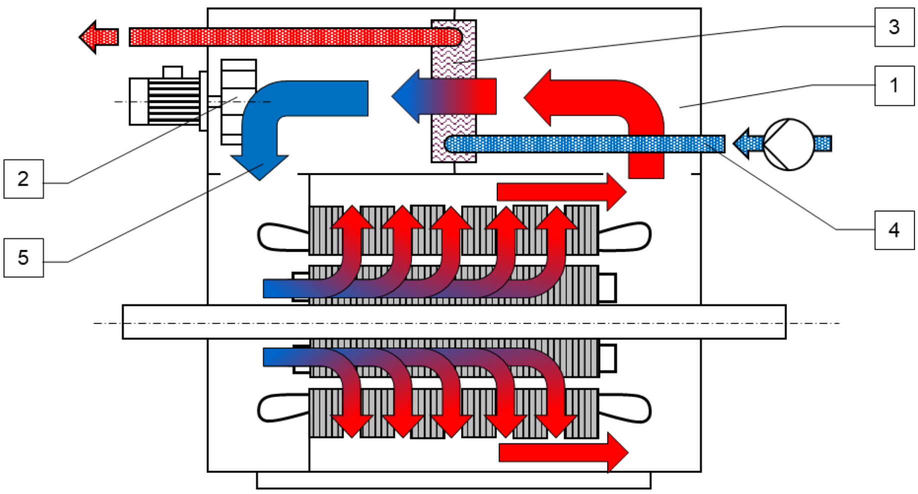




2.3 Protection degree and cooling type

Protection degree: IP 44 (for PMSG IP 54 on request)

Cooling type: IC 8 A6 W7, short form: IC 86W



(1) Cooler hood
(2) Fan
(3) Water cooler
(4) Water circle
(5) Air circuit

Schematic diagram

2.4 Construction type

The slip-ring excited and permanently excited shaft generators are preferably supplied in the following design:

- IM 5416

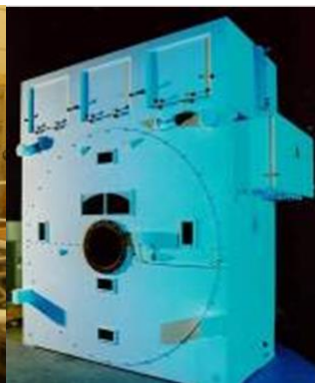
2.5 Technical conception

An important criterion for the selection of the shaft generator is the matching of the electrical output power with the mechanical power given to the shaft train depending on its speed range. For shaft systems with generator and motor operation, the power range to be realized in both energy flow directions must be taken into account.

The optimum adaptation of the machine is carried out starting from a rated operating point, which is given by the combination of the values operating mode, power, speed, voltage and power factor, and via the required variation of these variables over a defined speed range.

Of course, further requirements for the shaft generator resulting from the conditions onboard the vessel, such as compliance with the type of protection, cooling type, design, bearings, foundation and the dimensioning of the excitation data in adaptation to a given excitation system and the influence on grid stability and grid quality must be taken into account.

VEM's project planning provides the answer to these questions and helps to select the right generator.



3 Type designation, standards and regulations

3.1 Type designation

The type designations of VEM Sachsenwerk is made up of letters and numbers.

Letters	Digit 1-5
Digits _	Digit 10-11
Letters digit	12-13

	D	G	M	U	W	1	1	4	5	-	1	6	U		
Position	1	2	3	4	5	6	7	8	9		10	11	12	13	14

1	Current type D = three-phase current
2	Machine type G = Synchronous generator with slip ring (EESG) P = Synchronous generator permanently excited (PMSG)
3	Cooling mode, protection class M = closed circuit cooling with water cooler and ventilation unit IP 44 (for permanent magnet excited (PM) generators IP 54 on request)
4	Intended use U =Ship applications
5	Voltage W = LV (up to 1000 V) X = HV (up to 6600 V) Z = Special voltage
6 and 7	Shaft height H (coded)
8 and 9	Iron core length (coded)
10 and 11	Number of poles
12 to 14	Code letters for special winding designs, pole design and reworking stages

3.2 Standards and regulations

Our shaft generators comply with the applicable DIN standards and the IEC standards. For basic versions, these are in particular DIN EN 60034 (VDE 0530) and IEC 60034 with their respective parts:

Part 1 Design and operational performance
DIN EN 60034-1 (VDE 0530-1) - IEC 60034-1

Part 2 Method for determining the losses of efficiency ...
DIN EN 60034-2- ... (VDE 0530-2- ...) - IEC 60034-2- ...(several parts)

Part 4 Method for determining the characteristics of synchronous machines by measurement
DIN EN 60034-4; (VDE 0530-4)

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 Designation for construction types
DIN EN 60034-7 (VDE 0530-7) - IEC 60034-7

Part 8 Terminal markings and direction of rotation
DIN EN 60034-8 (VDE 0530-8) - IEC 60034-8

Part 15 Test methods and test voltages for main insulation and winding insulation of sample coils
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- ... (several parts)

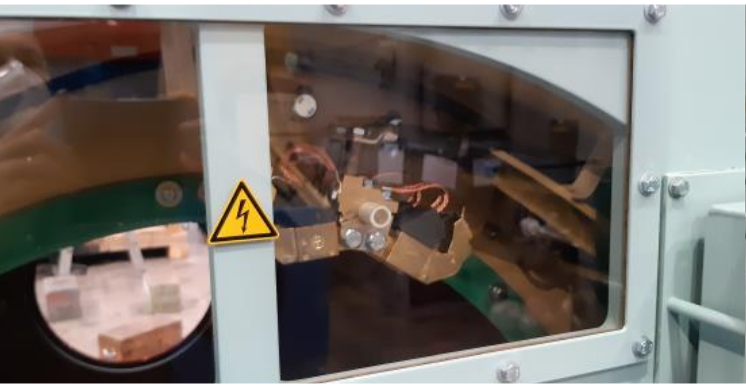
Part 27 Off-line partial discharge measurements on stator winding insulation of rotating machinery
DIN CLC/TS 60034-27; VDE V 0530-27

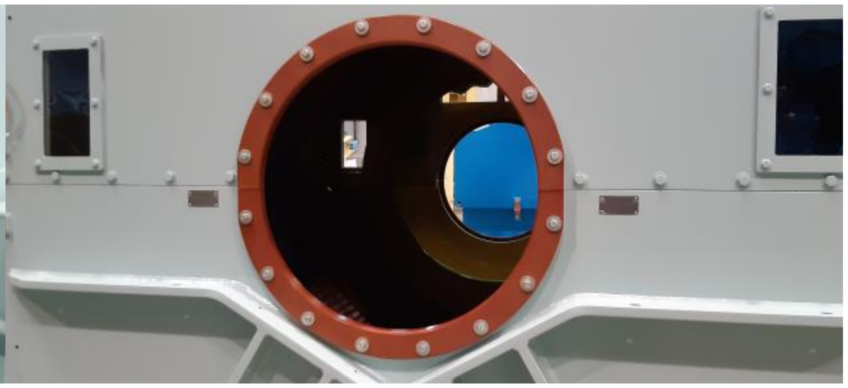
Part 29 Method of equivalent load and superposition -.
Indirect test for determination of temperature rise
DIN EN 60034-29; VDE 0530-29

and

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

Delivery according to other standards is possible on request, e.g. the IEC standards being coordinated and the regulations of all major ship classification societies.





4 Properties and operating behavior

4.1 Voltage and frequency

The basic version of these generator series is available with rated voltage 590 V / 690 V, 4.1 kV and 6.6 kV and for a frequency range, which depending on the speed of the ship's skin shaft, lies in the range from 5 Hz to 36 Hz.

Deviation from these values is possible on request.

4.2 Stator winding circuit

The stator winding is designed as a three-phase winding, which is connected in star. A distinction is made between machines with a single three-phase winding and those with two three-phase windings. Machines with two three-phase windings are designed with either 0° or 30° phase shift between the two three-phase windings. The star point can be open for the installation of protection and measuring transformers.

4.3 Overload capacity

The shaft generators are designed for an overload with 1.5 times the rated current during a time period of 120 s. Within six hours, the machines can be operated with 1.1 times the rated current for a period of one hour.

4.4 Ship classification

Depending on the classification regulation, somewhat lower limit values are permitted compared to IEC [1] with regard to the permissible winding overtemperatures. Thus, a corresponding power reduction may become necessary.

Overload requirements / permissible heating

Classification regulation	Coolant tempera-ture [°C] Cold air [°C]	Permissible Stator winding heating for thermal class 155(F) [K]	Overload and du-ration	S/S_N
IEC 60034-1	40	105	50 % for 30 s	1,0
DNV	45	95	50 % for 2 min	0,95
Bureau Veritas	50	90	50 % for 2 min	0,925
Lloyd's Register of Shipping	45	90	50 % for 15 s	0,95
RINA	50	90	50 % for 2 min	0,925
American Bureau of Shipping	50	90	-	0,925

5 Design description

5.1 Stator

The stator consists of a welded construction with a shrink-fit stator core. The stator laminations are made of insulated dynamo sheet segments and axially clamped by means of press bolts.

The three-phase two-layer winding is located in the slots of the laminated core. The form coils are made of foil-mica insulated flat copper wire. The main insulation consists of low-binder mica-glass tapes. To prevent corona discharges, a low-impedance mica protective coating is applied in the slot section and a high-impedance mica protective coating is applied at the slot outlet of high-voltage machines.

The completely insulated coils are fixed in the slots by means of slot locks. The connections are brazed. The stator winding is vacuum pressure impregnated by means of epoxy resin (insulation system VEMoDUR®-VPI-155).

5.2 Rotor

5.2.1 Rotor design for electrically excited shaft generators

Each shaft generator has 16 poles made of stamped dynamo sheets. By means of press plates at the ends and rivets, the dynamo sheets are braced and form a torsionally rigid sheet body.

The pole coils are made of enameled copper wire with enamel-glass insulation and are each wound directly onto the single pole. A damper winding is arranged in the pole roofs. This consists of copper rods which are soldered to the damper segments.

5.2.2 Rotor design for permanent magnet excited (PM) shaft generators

The poles are made of neodymium-iron-boron magnets mounted on a rotor carrier and secured against environmental and mechanical influences. The selection of the appropriate magnet material grading prevents demagnetization of the magnets in the event of a short circuit, even at high magnet temperatures. Before delivery, the rotor with the magnets is fixed and delivered together with the stator. On the ship, the rotor is connected to the propeller shaft and the fixation is released.

5.3 Cooler

The cooler housing is designed for IC 8 A6 W7 ventilation type (forced air-water cooling). The air-water heat exchanger is integrated as a double tube cooler. Furthermore, there are a forced cooling fans on the cooler housing, depending on the cooling capacity required.

The main cable connection and necessary current and voltage transformers are located in the cooler housing. In the case of machines working on the passive rectifier, this is also integrated in the ventilation hood and is cooled by the cooling air flow of the machine. The main connection cables can be fed from the left or right and from the bottom or top.

The cooler housing is equipped with emergency air flaps to cool the generator directly with ambient air in the event of failure of the cooling water circuit. In this way, operation with reduced power still can be guaranteed.

5.4 Slip ring

Electrically excited shaft generators are excited by means of slip rings. The slip ring is self-ventilated by the ambient air. The two slip rings are divided into two parts so that they can be mounted around the ship's shaft. A certain number of graphite brushes run on these, depending on the required rated excitation current.

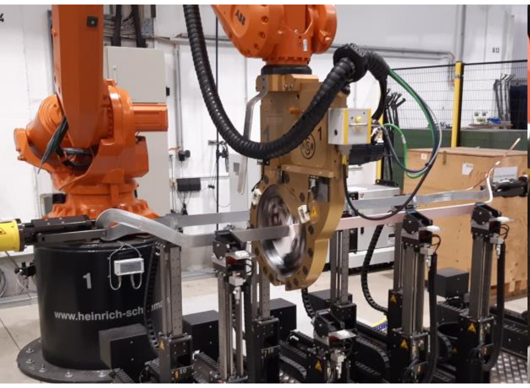
5.5 Pole wheel position sensor

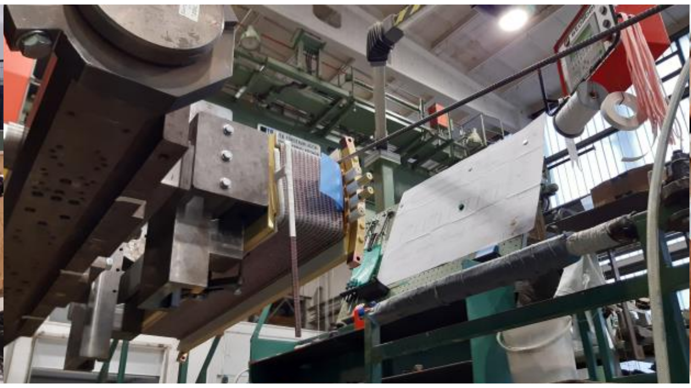
For the operation of the PM shaft generator, a rotor position sensor is always prescribed by the converter manufacturer. This is included in our design if the generator is supplied by us with main shaft and bearing. Mostly for slow-running shaft generators, the shaft and bearing are not included in the scope of supply of the generator manufacturer. Thus the pole wheel position sensors, which are placed around the propeller shaft e.g. as a band, must be provided by the system integrator.

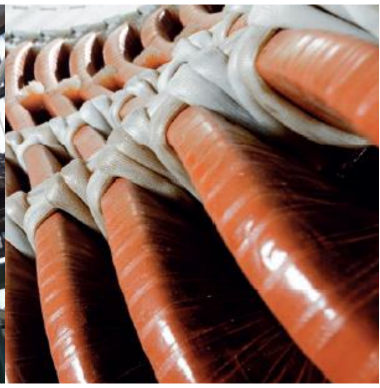
5.6 Monitoring

The generator is monitored by:

- 3x PT100 in stator winding + 3x reserve
- optional PT 100 for cooling air
- Leakage monitoring of the water coolers, which are designed as double-pipe coolers
- The connection of the monitoring cables is possible from terminals in 2-, 3- or 4-wire technology.







6 VEMoDUR insulation system

The operational reliability of electrical machines is decisively determined by the quality of their winding insulation. Characteristic for the insulation technology of VEM Sachsenwerk GmbH are and have always been technical solutions which define the international standard in their quality parameters and thus ensure products with high reliability and long life cycles for the owners. VPI technology is used for the insulation of high and low voltage machines in all power ranges. The corresponding insulation system VEMoDUR®-VPI-155 was developed at VEM Sachsenwerk and tested according to IEC [2]. Due to decades of operating experience, it is also available as a reference system for future comparative functional evaluations [3]. The components of the insulation system, consisting of winding and main insulation with a high mica content and epoxy resin, optimally match to each other. During the impregnation process, the insulation is subject to a continuous control system, whereby characteristic values such as:

- Viscosity of the resin
- Impregnation and hardening temperature
- Pressure holding times
- Negative and positive pressure
- PD level measurements

are checked and documented. The insulation cures in a rotating process.

The VPI process guarantees high mechanical strength, especially of the winding heads, and excellent electrical strength, particularly for flashover voltages. Rated impulse voltages according to IEC [4] for all generators with a high degree of safety are guaranteed.

The insulation system is characterized by high climate resistance, i.e. the winding is insensitive to moisture and aggressive atmosphere.

Within the scope of the routine tests, electrical intermediate and final tests of the insulation strength including the shock and partial discharge test are carried out. At the customer's request, these test steps can be agreed and carried out separately.

7 Quality assurance, documentation, shipping, packaging, commissioning and service

7.1 Quality assurance

Consistently high quality of our products, high customer satisfaction and sustainable processes are part of our company policy and elementary components of our thinking and acting.

The management system of VEM Sachsenwerk GmbH is an Integrated Management System consisting of the certified systems according to DIN EN ISO 9001, DIN EN ISO 14001 and DIN EN ISO 50001.

Our quality assurance monitors the complete manufacturing process of our products, starting with development, through incoming goods inspection and the manufacturing process to final inspection and delivery of the machine. For this purpose, more than 50 experts are available to us with their expertise, for example in the 3-D measuring room.

At the end of the assembly process, each machine is subjected to an internal final test in one of our four test bays. The respective scope of testing results from the applicable standards, rules and regulations, from customer requirements and from internal requirements of various departments. We distinguish between a standard "Routine Test" according to IEC 60034-1 or an extended "Type Test".

Depending on the type of project, tests are supervised and accepted by classification societies, supervisory authorities or independent third parties. Customer acceptance tests are possible upon request.

Load tests with up to 6 MW continuous load in a wide speed range are possible in our modern large machine test bay. The variable-frequency power supply with a voltage range from 400 V to 15 kV allows us to optimally adapt to the testing requirements of a wide variety of machine designs. Extensive measurement equipment enables the performance of special tests, such as thermography, structure-borne sound measurements or partial discharge diagnosis.

The results of these tests are documented in a test report. Upon delivery note, each machine receives a 3.1 certificate according to EN 10204 as part of the documentation. This clearly summarizes the most important test results.

7.2 Documentation

Part of the delivery is standard documentation in PDF format and / or 3 hardcopies:

- Safety instructions
- Product description
- Instruction for transport and storage
- Assembly instruction
- Instruction for commissioning
- Warning and shutdown values
- Operation with troubleshooting
- Maintenance and inspection
- Disposal
- Technical data sheet
- Drawings:
  - Dimension drawing generator
  - Dimension drawing connection box
  - Connection diagram
- 3.1 certificate
- Type test report, if option type test was ordered
- if applicable, documentation of external supplier parts (options)

The following data can be provided in a CAD format:

- Dimensional drawing in DXF format (for standard version without surcharge)
- 3D model of the outer shell in STP format (for standard version without surcharge)

The delivery of further documents on request.

Documentation is provided in German and English at no extra charge. Delivery in EU languages is possible, other languages on request.

Documentation according to customer specifications must be requested separately.

7.3 Shipping, packing, assembly

The type of packaging depends on the design of the machines and the agreed transport and storage conditions.

All packaging requirements can be realized in accordance with HPE guidelines. For this purpose, we have cooperation partners at our disposal who pack on site or on the premises of VEM.

The electrically excited shaft generators are always shipped in dismantled condition. Depending on the transport height, the stator is delivered with the cooler housing mounted or unmounted. The single poles and slip ring are always shipped separately. At the shipyard, the ship's main shaft is then pushed through the stator bore, after which the individual poles and slip rings are mounted on the ship's shaft, and finally the stator is moved over the finished pole wheel and aligned.

Long-term cooperation with specialized companies guarantees the successful transport of even the bulkiest parts.

We recommend that the necessary installation and commissioning work be carried out by our specialist personnel. If the customer carries out the work himself or by commissioning third parties, the execution must be documented accordingly.

However, liability and warranty by VEM are excluded if this proof cannot be provided.

7.4 Service

With the delivery of your generator, our customer service is available to you as your first contact. The team supports you with a wide range of services.

7.4.1 Test house services and contract manufacturing

Due to our modern and powerful testing technology, we are able to offer you comprehensive test house services such as routine, type and system testing as a neutral partner. On request, we also realize special tests within the scope of product developments. Our company has the specialists required for this and extensive experience with the testing requirements of a wide range of acceptance organizations at home and abroad.

Upon your request, we will prepare detailed test plans.

7.4.2 Mechanical analyses for condition and fault diagnosis

Knowledge of the current condition of technical equipment and knowledge of possible failure before damage occurs increases service life and avoids expensive downtime and repairs. For this purpose, VEM prepares and evaluates vibration analyses that include not only the motors and generators but also your plant-specific environment.

7.4.3 Assembly and commissioning

Assembly, commissioning, repairs and inspections require a great deal of experience and sensitivity. The increasing complexity of machines and plants, dealing with on-site conditions and working under high deadline pressure can only be managed by experienced specialists. Our field assembly team meets these requirements time and again all over the world.

We work together with you to draw up schedules for your project, act on site with qualified personnel for assembly and supervision, and provide you with engineering support up to successful commissioning. Detailed reports and measurement protocols prove the quality of the work performed.

7.4.4 Technical services

We support you within the limitation period for liability for material defects and also offer you selected service modules to keep your systems permanently available after commissioning. Object-related service agreements define the specific type and scope of our services.

Our team works closely with the internal specialist departments such as electromagnetic and mechanical design. It can advise you on all questions relating to the machine and associated peripherals.

7.4.5 On-call service

You can reach us Monday to Friday from 08:00 to 17:00, excluding public holidays. You can arrange a further on-call service with us.

7.4.6 Maintenance

Experienced employees are at your disposal for the elaboration of maintenance and servicing plans. We will gladly take over the work necessary on your generators.

7.4.7 Inspection

Within the scope of inspections, we evaluate the actual condition of your drives from a mechanical and electrical point of view.

We determine the causes of conspicuous wear, derive necessary consequences and prepare spare parts recommendations. If the machines are operated and maintained in accordance with regulations, a warranty extension can be agreed.

7.4.8 Repair

As an economical alternative to a new generator, we offer high quality repairs and upgrades of electric machines, most of which are carried out in our factory.

7.4.9 Training

We train your personnel on site or in our factory.

7.4.10 Spare parts supply

Our competent team is your contact for all technical and commercial questions on the subject of spare parts procurement and stocking. For a quick service in case of damage, a spare parts warehouse on site is helpful.

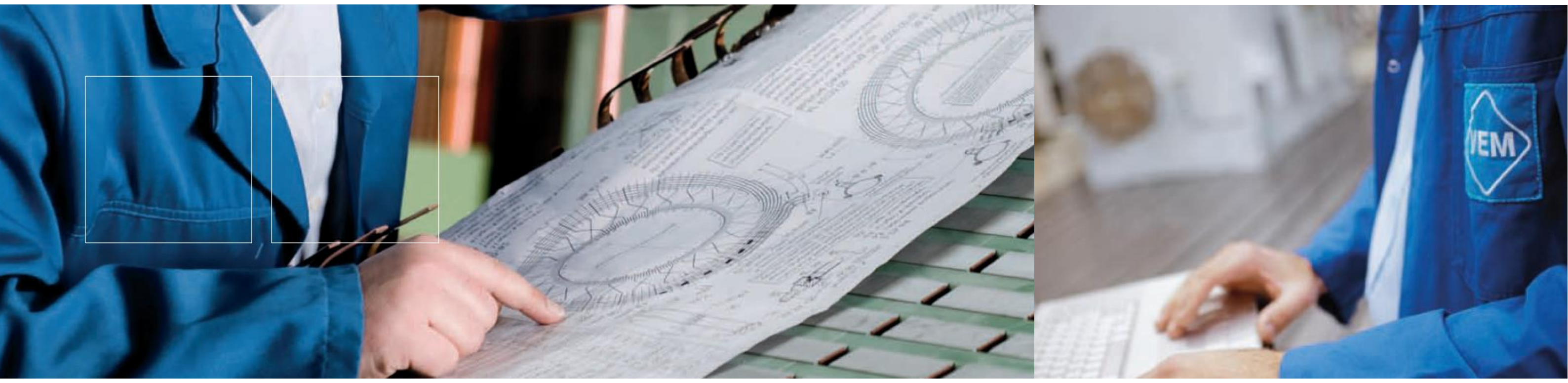
We will be happy to provide you with a suitable recommendation for this.

On request, we can also hold your fault reserve at our plant in Dresden.

7.5 General notes

Unless otherwise specifically requested and offered, the machine(s) will be designed as follows:

- Winding production is carried out with the VEMoDUR insulation system.
- Painting is carried out according to factory standard SW-N 170-004, which is based on DIN EN ISO 12944/31-8 DIN 55928 part 8+9 and with applicable standards.
- The direction of rotation of the machine is clockwise, looking at its drive end (DE).
- The terminal box is located on the right, looking at its drive end (DE).
- For the main cable outlet, the cover plate is undrilled, without cable glands.
  A main cable outlet with cable glands or packing frames according to customer specifications are optionally available.
- The cooler is located on the machine and the water connection is located on the left, looking at the drive end (DE).
- The water cooler is without water monitoring up to the connection flange.
- The water cooler is designed as a double-pipe cooler with leakage monitoring.
- PT 100 for winding and cooling air in 2-wire circuit without release unit, from terminal box connection in 2-, 3- and 4-wire version.
- Mechanical vibrations comply with the limits specified in IEC 60034-14 and are verified in VEM's test field.
- An evaluation unit for vibration monitoring is not part of the VEM scope of delivery.



8 Technical data and dimensions

8.1 Electrically excited wave generators

8.1.1 Shaft height 900 mm

Example calculations for rated speed 75 rpm and maximum speed of 110 rpm at rectifier load; forced-ventilated machines with water cooler (IC 86W), cooling water temperature 38 °C, utilization F/F

Typ	Drehzahl	Leistung	Spannung	Leistungs-faktor	Strom	Dreh-moment	Wellen-leistung	Reaktanzen		Wirkungsgrad		
	n_n / n_{max} [1/min]	S_n [kVA]	U_n [V]	$\cos\varphi$ [V]	I [A]	M_n [kNm]	P_{mech} [kW]	x_d'' [%]	x_q'' [%]	$\eta_{4/4}$ [%]	$\eta_{3/4}$ [%]	$\eta_{1/2}$ [%]
DGMUW 9018-16U	75 110	480,0	590,0	0,96 (+)	469,7	61,1	522,2	34,30 50,50	29,50 43,50	88,23 90,27	90,30 91,96	91,65 93,42
DGMUW 9020-16U	75 110	530,0	590,0	0,96 (+)	518,6	67,5	572,6	34,20 50,40	29,40 43,20	88,86 90,68	90,79 95,30	92,04 93,69
DGMUW 9022-16U	75 110	600,0	590,0	0,96 (+)	587,1	76,4	646,1	33,90 50,00	29,00 42,70	89,15 91,02	91,01 92,57	92,23 93,89
DGMUW 9025-16U	75 110	700,0	590,0	0,96 (+)	685,0	89,1	752,7	34,80 51,20	29,60 43,60	89,28 91,06	91,18 92,63	92,44 93,99
DGMUW 9028-16U	75 110	780,0	590,0	0,96 (+)	763,3	99,3	832,2	32,70 48,30	27,80 40,90	89,98 91,79	91,65 93,19	92,70 94,34
DGMUW 9032-16U	75 110	900,0	590,0	0,96 (+)	880,7	114,6	959,0	31,10 45,90	26,30 38,70	90,09 92,11	91,81 93,43	92,75 94,50
DGMUW 9036-16U	75 110	1000,0	590,0	0,96 (+)	978,6	127,3	1063,7	32,20 47,60	27,20 40,00	90,25 91,93	91,88 93,31	92,91 94,46
DGMUW 9040-16U	75 110	1100,0	590,0	0,96 (+)	1076,4	140,1	1165,3	32,30 47,60	27,10 39,90	90,62 92,17	92,17 93,50	93,13 94,61

8.1.2 Shaft height 1120 mm

Example calculations for rated speed 75 rpm and maximum speed of 110 rpm at rectifier load; forced-ventilated machines with water cooler (IC 86W), cooling water temperature 38 °C, utilization F/F

Typ	Drehzahl n_n / n_{max} [1/min]	Leistung S_n [kVA]	Spannung U_n [V]	Leistungs-faktor $\cos\varphi$ [V]	Strom I [A]	Dreh-moment M_n [kNm]	Wellen-leistung P_{mech} [kW]	Reaktanzen x_d'' [%]	x_q'' [%]	Wirkungsgrad $\eta_{4/4}$ [%]	$\eta_{3/4}$ [%]	$\eta_{1/2}$ [%]
DGMUW 1122-16U	75 110	1150,0	590,0	0,96 (+)	1125,3	146,4	1203,8	32,90 48,70	28,00 41,30	91,71 92,72	93,20 94,02	94,23 95,12
DGMUW 1125-16U	75 110	1320,0	590,0	0,96 (+)	1291,7	168,1	1374,8	27,80 41,50	23,60 35,00	92,17 93,81	93,69 94,82	94,36 95,59
DGMUW 1128-16U	75 110	1500,0	590,0	0,96 (+)	1467,8	191,0	1559,8	27,30 40,90	23,10 34,30	92,32 93,97	93,82 94,95	94,47 95,69
DGMUW 1132-16U	75 110	1700,0	590,0	0,96 (+)	1663,6	216,5	1737,5	26,60 39,80	22,40 33,20	93,93 94,38	94,20 95,27	94,73 95,91
DGMUW 1136-16U	75 110	1900,0	590,0	0,96 (+)	1859,3	241,9	1960,4	28,50 42,40	23,80 35,20	93,04 94,05	94,17 95,04	94,85 95,82
DGMUW 1140-16U	75 110	2100,0	590,0	0,96 (+)	2055,0	267,4	2165,2	24,40 36,80	20,40 30,40	93,11 94,68	94,31 95,48	94,73 96,04
DGMUW 1145-16U	75 110	2400,0	590,0	0,96 (+)	2348,5	305,6	2466,3	25,70 38,60	21,40 31,80	93,42 94,69	94,51 95,52	94,97 96,11
DGMUW 1150-16U	75 110	2700,0	590,0	0,96 (+)	2642,1	343,8	2771,3	25,80 38,60	21,40 31,80	93,53 94,80	94,62 95,61	95,08 96,19

8.1.3 Shaft height 1400 mm

Example calculations for rated speed 65 rpm and maximum speed of 100 rpm at rectifier load; forced-ventilated machines with water cooler (IC 86W), cooling water temperature 38 °C, utilization F/F

Typ	Drehzahl n_n / n_{max} [1/min]	Leistung S_n [kVA]	Spannung U_n [V]	Leistungs-faktor $\cos\varphi$ [V]	Strom I [A]	Dreh-moment M_n [kNm]	Wellen-leistung P_{mech} [kW]	Reaktanzen x_d'' [%]	x_q'' [%]	Wirkungsgrad $\eta_{4/4}$ [%]	$\eta_{3/4}$ [%]	$\eta_{1/2}$ [%]
DGMUW 1425-16U	65 100	2000,0	590,0	0,96 (+)	1957,1	293,8	2067,6	31,30 49,40	26,40 41,30	92,86 93,60	94,14 94,78	95,00 95,80
DGMUW 1428-16U	65 100	2250,0	590,0	0,96 (+)	2201,8	330,6	2325,3	32,90 51,60	27,50 42,80	92,89 93,43	94,18 94,67	95,10 95,77
DGMUW 1432-16U	65 100	2650,0	590,0	0,96 (+)	2593,2	389,3	2722,0	29,80 47,10	24,80 38,80	93,46 94,21	94,62 95,26	95,36 96,15
DGMUW 1436-16U	65 100	3000,0	590,0	0,96 (+)	2935,7	440,7	3075,3	30,00 47,50	24,90 38,90	93,65 94,30	94,76 95,34	95,48 96,22
DGMUW 1440-16U	65 100	3300,0	590,0	0,96 (+)	3229,2	484,8	3371,3	28,50 45,10	23,50 36,80	93,97 94,63	94,98 95,59	95,60 96,38
DGMUW 1445-16U	65 100	3700,0	590,0	0,96 (+)	3620,7	543,6	3779,1	26,80 42,70	22,10 34,60	93,99 94,74	94,97 95,66	95,56 96,41
DGMUW 1450-16U	65 100	4000,0	590,0	0,96 (+)	3914,2	587,6	4084,7	27,80 43,90	22,70 35,50	94,01 94,76	94,99 95,69	95,63 96,46
DGMUW 1456-16U	65 100	4500,0	590,0	0,96 (+)	4403,5	661,1	4578,7	29,50 46,30	23,90 37,20	94,35 94,73	95,29 95,68	95,89 96,49

8.1.4 Shaft height 1600 mm, voltage 4100 V

Example calculations for rated speed 65 rpm and maximum speed of 100 rpm at rectifier load; forced-ventilated machines with water cooler (IC 86W), cooling water temperature 38 °C, utilization F/F

Typ	Drehzahl n_n / n_{max} [1/min]	Leistung S_n [kVA]	Spannung U_n [V]	Leistungs-faktor $cos\,\varphi$ [V]	Strom I [A]	Dreh-moment M_n [kNm]	Wellen-leistung P_{mech} [kW]	Reaktanzen x_d'' [%]	 x_q'' [%]	Wirkungsgrad $\eta_{4/4}$ [%]	 $\eta_{3/4}$ [%]	 $\eta_{1/2}$ [%]
DGMUZ 1632-16W	65 100	4000,0	4100,0	0,96 (+)	281,6	587,6	4068,7	24,10 38,50	21,70 34,10	94,38 95,26	95,44 96,06	95,90 96,68
DGMUZ 1636-16W	65 100	4500,0	4100,0	0,96 (+)	316,8	661,1	4565,1	25,50 40,40	22,70 35,50	94,63 95,14	95,53 95,99	96,06 96,67
DGMUZ 1640-16W	65 100	5000,0	4100,0	0,96 (+)	352,0	734,6	5062,8	26,00 41,10	23,00 36,00	94,81 95,22	95,68 96,06	96,21 96,75
DGMUZ 1645-16W	65 100	5600,0	4100,0	0,96 (+)	394,3	822,7	5659,5	26,60 41,90	23,40 36,50	94,99 95,31	95,83 96,14	96,35 96,82
DGMUZ 1650-16W	65 100	6300,0	4100,0	0,96 (+)	443,6	925,5	6354,9	23,40 37,20	20,60 32,30	95,17 95,67	95,92 96,40	96,32 96,96
DGMUZ 1656-16W	65 100	7000,0	4100,0	0,96 (+)	492,9	1028,4	7047,7	22,10 35,30	19,40 30,50	95,35 95,87	96,03 96,54	96,36 97,04
DGMUZ 1663-16W	65 100	8000,0	4100,0	0,96 (+)	563,3	1175,3	8050,3	20,90 33,60	18,30 28,90	95,40 96,13	96,15 96,73	96,40 97,16
DGMUZ 1671-16W	65 100	9000,0	4100,0	0,96 (+)	633,7	1322,2	9042,4	22,40 35,70	19,50 30,60	95,55 95,98	96,21 96,64	96,54 97,14

8.1.5 Shaft height 1600 mm, voltage 6600 V

Example calculations for rated speed 65 rpm and maximum speed of 100 rpm at rectifier load; forced-ventilated machines with water cooler (IC 86W), cooling water temperature 38 °C, utilization

Typ	Drehzahl n_n / n_{max} [1/min]	Leistung S_n [kVA]	Spannung U_n [V]	Leistungs-faktor $cos\,\varphi$ [V]	Strom I [A]	Dreh-moment M_n [kNm]	Wellen-leistung P_{mech} [kW]	Reaktanzen x_d'' [%]	 x_q'' [%]	Wirkungsgrad $\eta_{4/4}$ [%]	 $\eta_{3/4}$ [%]	 $\eta_{1/2}$ [%]
DGMUX 1632-16V	65 100	3650,0	6600,0	0,96 (+)	319,3	536,2	3715,4	24,10 38,30	21,80 34,20	94,31 94,91	95,19 95,77	95,68 96,44
DGMUX 1636-16V	65 100	4100,0	6600,0	0,96 (+)	358,7	602,3	4176,6	24,50 38,90	22,00 34,50	94,24 94,75	95,16 95,66	95,72 96,40
DGMUX 1640-16V	65 100	4500,0	6600,0	0,96 (+)	393,6	661,1	4570,5	23,70 37,60	21,20 33,20	94,52 94,99	95,36 95,85	95,85 96,52
DGMUX 1645-16V	65 100	5000,0	6600,0	0,96 (+)	437,4	734,6	5068,1	22,90 36,30	20,30 31,90	94,71 95,17	95,49 95,98	95,93 96,61
DGMUX 1650-16V	65 100	5600,0	6600,0	0,96 (+)	489,9	822,7	5657,2	21,30 34,00	18,90 29,80	95,03 95,56	95,71 96,27	96,03 96,79
DGMUX 1656-16V	65 100	6300,0	6600,0	0,96 (+)	551,1	925,5	6363,0	22,90 36,30	20,20 31,60	95,05 95,42	95,77 96,19	96,18 96,79
DGMUX 1663-16V	65 100	7100,0	6600,0	0,96 (+)	621,1	1043,1	7152,2	20,30 32,50	17,90 28,20	95,30 95,84	95,92 96,48	96,17 96,93
DGMUX 1671-16V	65 100	8000,0	6600,0	0,96 (+)	699,8	1175,3	8057,1	21,10 33,60	18,50 29,00	95,32 95,76	95,95 96,44	96,26 96,93

8.2 Permanent Magnet Excited (PM) Shaft Generators

The selection of a suitable frequency inverter for PM shaft generators depends on the maximum possible DC link voltage $U_{DC\_\max\_cold}$ on the one hand and on the other hand on the spread between rated n_n and maximum speed n_{max} depends.

The max. possible DC link voltage specified by the drive manufacturer $U_{DC\_\max\_cold}$ must not be exceeded at maximum speed and with cold magnets.

For the upper speed point n_{max} with constant power follows the voltage: $U_{n\_\max}$

$$U_{n\_\max\_warm} = U_{DC\_\max\_cold} \cdot Fak_{DC/AC} \cdot Fak_{cold/warm}$$

with the following factors:

- from DC to AC voltage (including 5% standard safety factor) $Fak_{DC/AC} = \frac{1}{\sqrt{2}} \cdot 0.95$
- Reduction of voltage (cold/warm magnets) $Fak_{cold/warm} = 0.94$

$$U_{n_{max_{warm}}} = U_{DC_{max_{cold}}} \cdot \frac{1}{\sqrt{2}} \cdot 0.95 \cdot 0.94$$

$$U_{n_{max_{warm}}} = U_{DC_{max_{cold}}} \cdot 0.63$$

From $U_{n_{max_{warm}}}$ the voltage at the rated point at rated speed can $U_{n\_n_n}$ be calculated:

$$U_{n\_n_n} = \frac{n_n}{n_{max}} \cdot U_{n_{max_{warm}}}$$

The required maximum inverter current at the lower rated point can now be calculated from the apparent power.

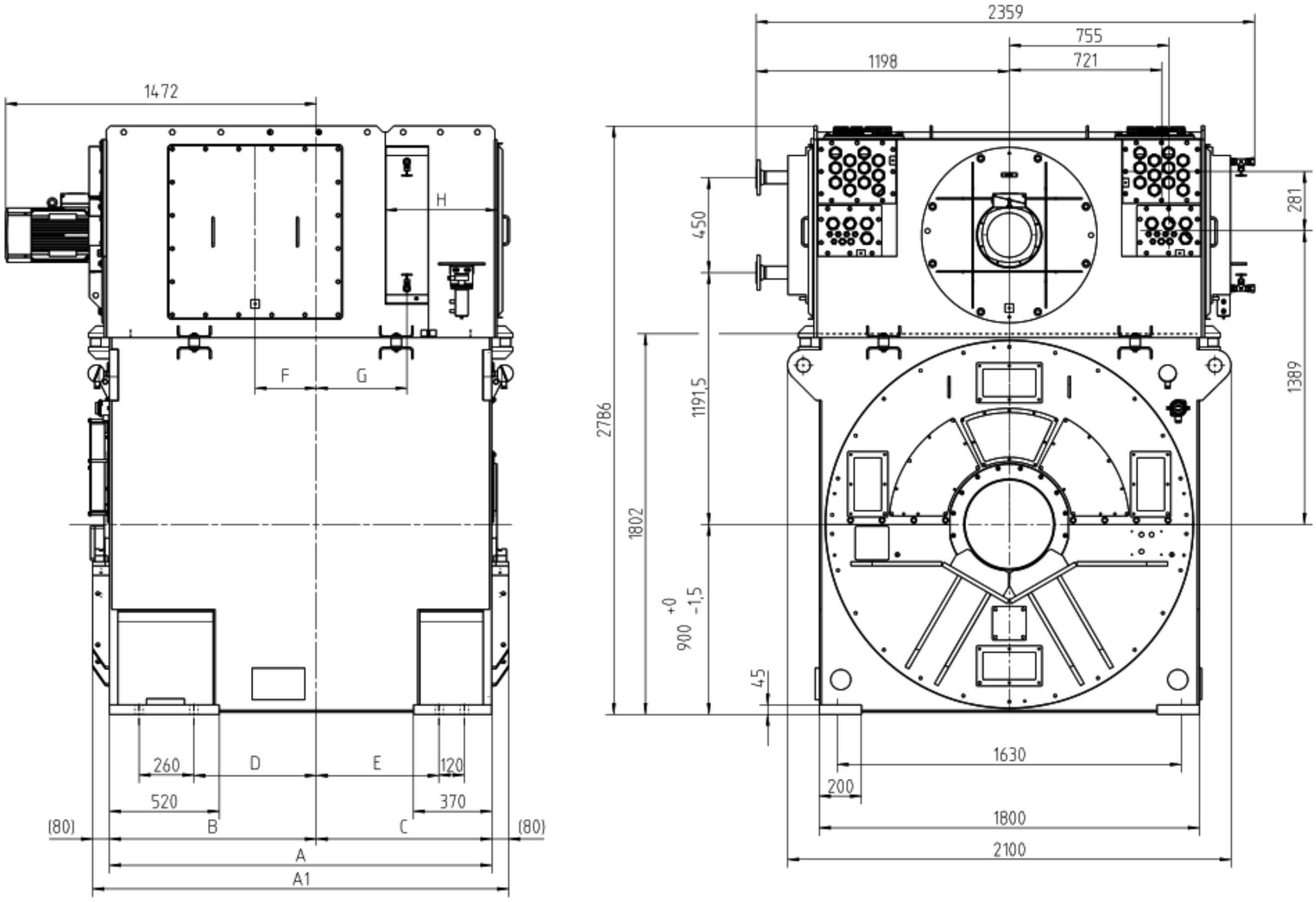
$$I_{n\_n_n} = \frac{S_n}{U_{n\_n_n} \cdot \sqrt{3}}$$

Example calculations for rated speed 100 rpm with operation at frequency converter; forced-ventilated machines with water cooler (IC 86W), cooling water temperature 38 °C, utilization F/F

Typ	Drehzahl n_n (n_{max}) [1/min]	Leistung S_n [kVA]	Spannung U_n [V]	Leistungs-faktor $\cos\varphi$ [V]	Strom I [A]	Drehmoment M_n [kNm]	Wellen-leistung P_{mech} [kW]	Wirkungsgrad η [%]
DPMUW 9018-20U	100 (200)	840	690	0,96	700	80	856	94,25
DPMUW 9020-20U	100 (200)	1050	690	0,96	880	100	1067	94,46
DPMUW 9022-20U	100 (200)	1150	690	0,96	960	110	1166	94,65
DPMUW 9025-20U	100 (200)	1260	690	0,96	1050	120	1273	94,99
DPMUW 9028-20U	100 (200)	1470	690	0,96	1230	140	1483	95,18
DPMUW 9032-20U	100 (200)	1570	690	0,96	1310	150	1581	95,36
DPMUW 9036-20U	100 (200)	1680	690	0,96	1410	160	1688	95,57
DPMUW 9040-20U	100 (200)	1880	690	0,96	1570	180	1884	95,80
DPMUW 1122-28U	100 (200)	1880	690	0,96	1570	180	1879	96,05
DPMUW 1125-28U	100 (200)	2090	690	0,96	1750	200	2088	96,10
DPMUW 1128-28U	100 (200)	2410	690	0,96	2020	230	2405	96,20
DPMUW 1132-28U	100 (200)	2930	690	0,96	2450	280	2919	96,35
DPMUW 1136-28U	100 (200)	3250	690	0,96	2720	310	3233	96,50
DPMUW 1140-28U	100 (200)	3770	690	0,96	3150	360	3747	96,60
DPMUW 1145-28U	100 (200)	3980	690	0,96	3330	380	3953	96,65
DPMUW 1150-28U	100 (200)	4500	690	0,96	3770	430	4468	96,69
DPMUW 1425-32U	100 (200)	2930	690	0,96	2450	280	2908	96,72
DPMUW 1428-32U	100 (200)	3350	690	0,96	2800	320	3322	96,81
DPMUW 1432-32U	100 (200)	4080	690	0,96	3410	390	4043	96,89
DPMUW 1436-32U	100 (200)	4500	690	0,96	3770	430	4450	97,07
DPMUW 1440-32U	100 (200)	5240	690	0,96	4380	500	5181	97,10
DPMUW 1445-32U	100 (200)	5650	690	0,96	4730	540	5584	97,13
DPMUW 1450-32W	100 (200)	6390	690	0,96	2 x 2675	610	6314	97,15
DPMUW 1456-32W	100 (200)	7120	690	0,96	2 x 2980	680	7035	97,17
DPMUW 1632-36W	100 (200)	6490	690	0,96	2 x 2715	620	6408	97,23
DPMUW 1636-36W	100 (200)	7120	690	0,96	2 x 2980	680	7028	97,25
DPMUW 1640-36W	100 (200)	8270	690	0,96	2 x 3460	790	8160	97,30
DPMUW 1645-36W	100 (200)	8900	690	0,96	2 x 3725	850	8777	97,35
DPMUW 1650-36W	100 (200)	10050	690	0,96	2 x 4205	960	9900	97,45
DPMUW 1656-36W	100 (200)	11310	690	0,96	2 x 4730	1080	11129	97,56
DPMUW 1663-36W	100 (200)	12460	690	0,96	2 x 5215	1190	12256	97,60
DPMUW 1671-36W	100 (200)	14240	690	0,96	2 x 5960	1360	13999	97,65
DPMUX 1632-36V	100 (200)	5760	6600	0,96	500	550	5706	96,91
DPMUX 1636-36V	100 (200)	6280	6600	0,96	550	600	6215	97,00
DPMUX 1640-36V	100 (200)	7440	6600	0,96	650	710	7356	97,10
DPMUX 1645-36V	100 (200)	7960	6600	0,96	700	760	7862	97,20
DPMUX 1650-36V	100 (200)	9010	6600	0,96	790	860	8896	97,23
DPMUX 1656-36V	100 (200)	10050	6600	0,96	880	960	9920	97,26
DPMUX 1663-36V	100 (200)	11100	6600	0,96	970	1060	10952	97,30
DPMUX 1671-36V	100 (200)	12670	6600	0,96	1110	1210	12496	97,34

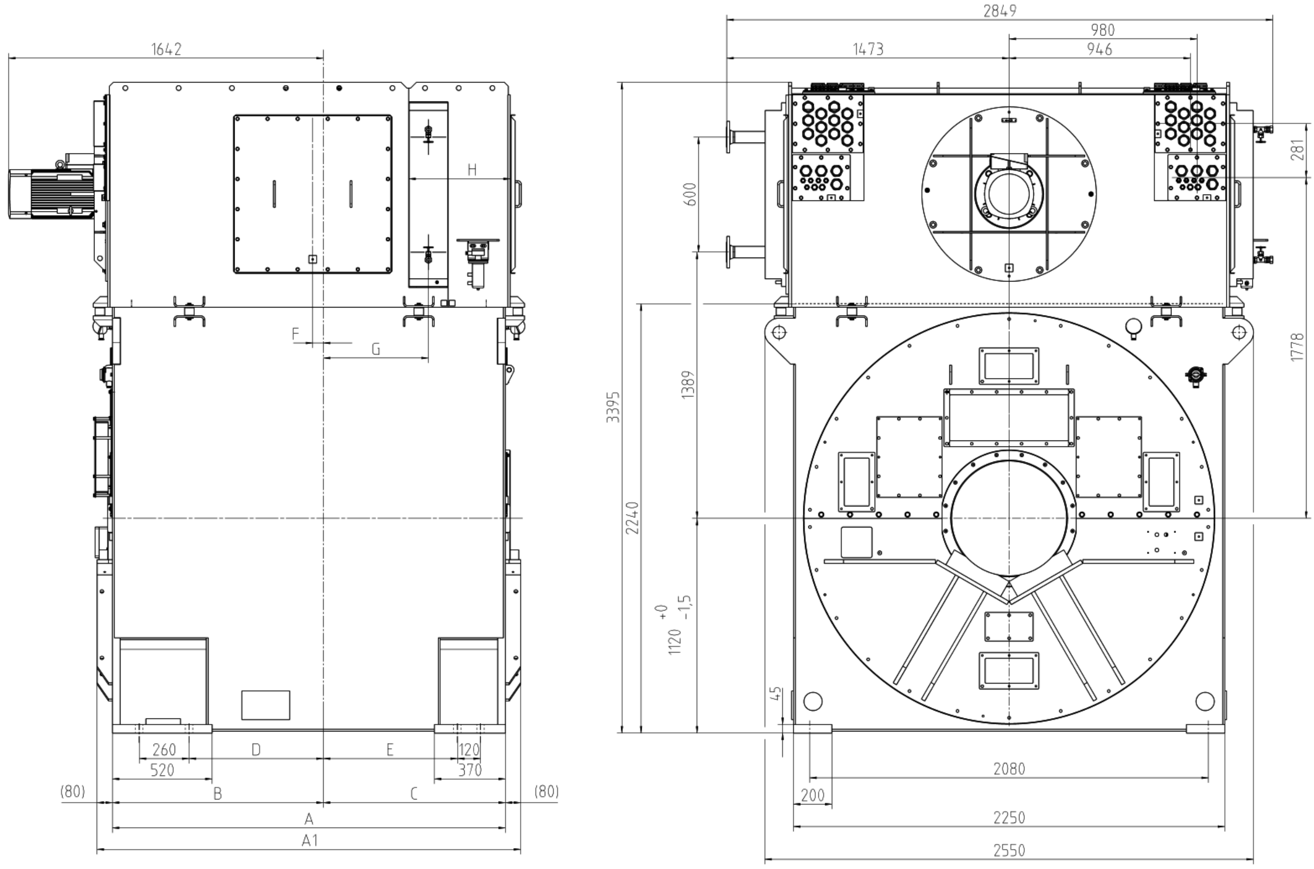
8.3 Dimension tables

8.3.1 Shaft height 900 mm



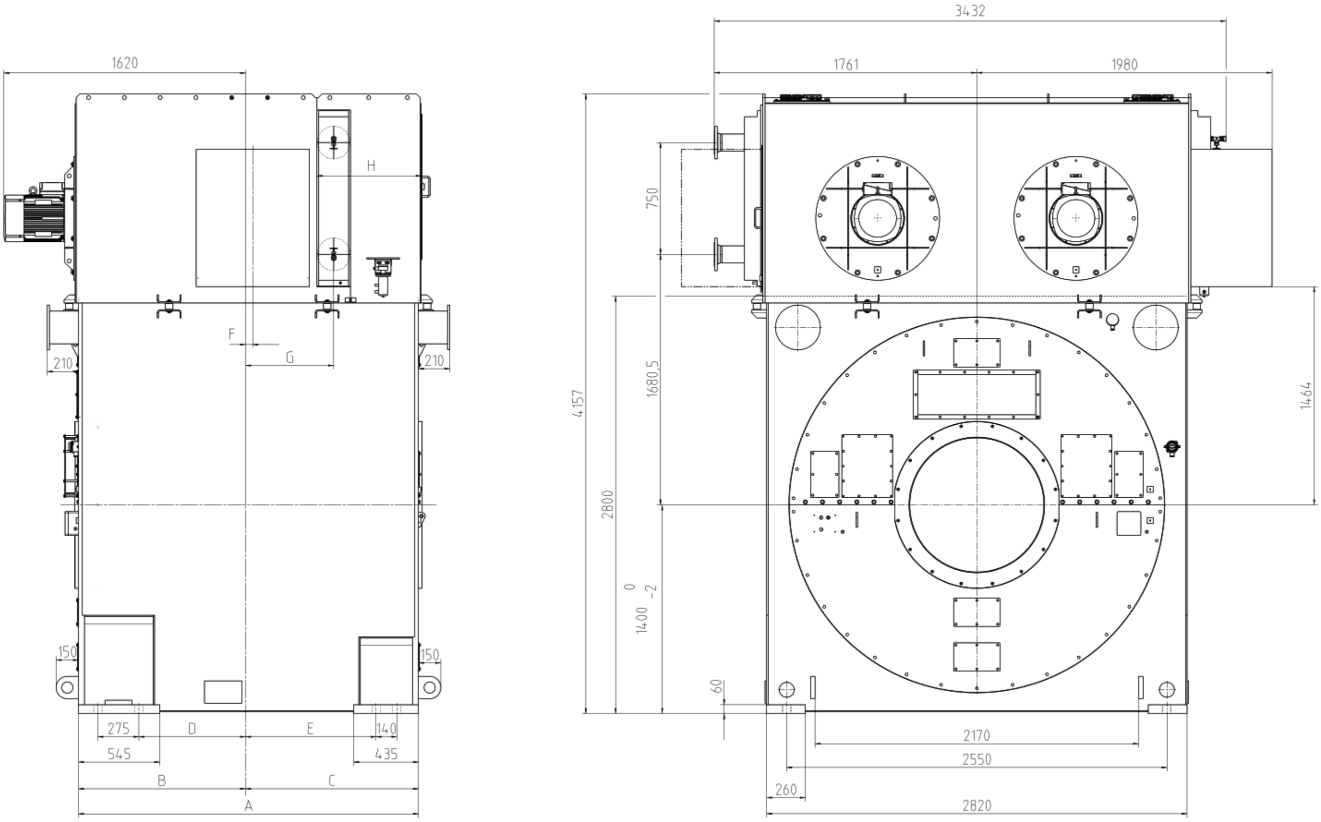
Type	A	A1	B	C	D	E	F	G	H	Gewicht ohne Rotor [kg] ± 5%
D_MUW 9018-__U	1810	1970	770	1040	370	790	80	638,5	529	10930
D_MUW 9020-__U			800	1010	400	760	110	608,5		11600
D_MUW 9022-__U			830	980	430	730	140	578,5		12300
D_MUW 9025-__U			875	935	475	685	185	533,5		13300
D_MUW 9028-__U			920	890	520	640	230	488,5		14230
D_MUW 9032-__U			980	830	580	580	290	428,5		15650
D_MUW 9036-__U	2050	2210	1040	1010	640	760	110	608,5		1700
D_MUW 9040-__U			1100	950	700	700	170	548,5		18400

8.3.2 Shaft height 1120 mm



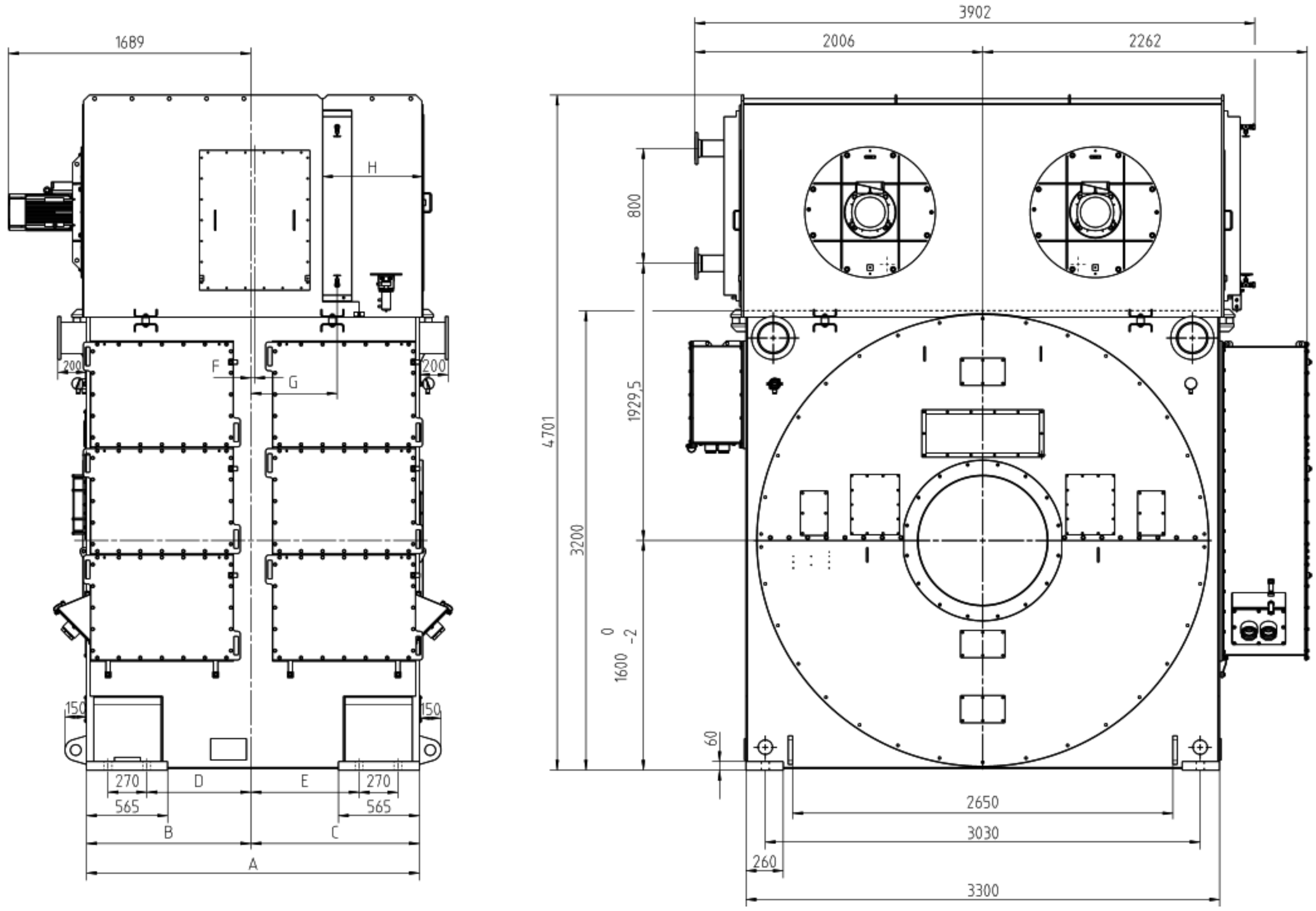
Type	A	A1	B	C	D	E	F	G	H	Gewicht ohne Rotor [kg] ± 5%
D_MUW 1122-__U	1810	1970	830	980	430	730	25	578,5	529	11250
D_MUW 1125-__U			875	935	475	685	70	533,5		12750
D_MUW 1128-__U			920	890	520	640	115	488,5		13275
D_MUW 1132-__U			980	830	580	580	175	428 5		14000
D_MUW 1136-__U	2050	2210	1040	1010	640	760	-5	608,5		15050
D_MUW 1140-__U			1100	950	700	700	55	548,5		15800
D_MUW 1145-__U	2350	2510	1175	1175	775	925	150	773,5		17100
D_MUW 1150-__U			1250	1100	850	850	225	698,5		18000

8.3.3 Shaft height 1400 mm



Type	A	B	C	D	E	F	G	H	Gewicht ohne Rotor [kg] ± 5%
D_MUW 1425-__U	2010	895	1115	490	830	7	546,5	700	17000
D_MUW 1428-__U		940	1070	535	785	52	501,5		19040
D_MUW 1432-__U		1000	1010	595	725	112	441,5		20045
D_MUW 1436-__U		1060	950	655	665	172	381,5		21072
D_MUW 1440-__U	2280	1120	1160	715	875	49	591,5		22615
D_MUW 1445-__U		1195	1085	790	800	26	516,5		23880
D_MUW 1450-__U	2610	1270	1340	865	1055	151	771,5		25794
D_MUW 1456-__U		1360	1250	955	965	241	681,5		27311

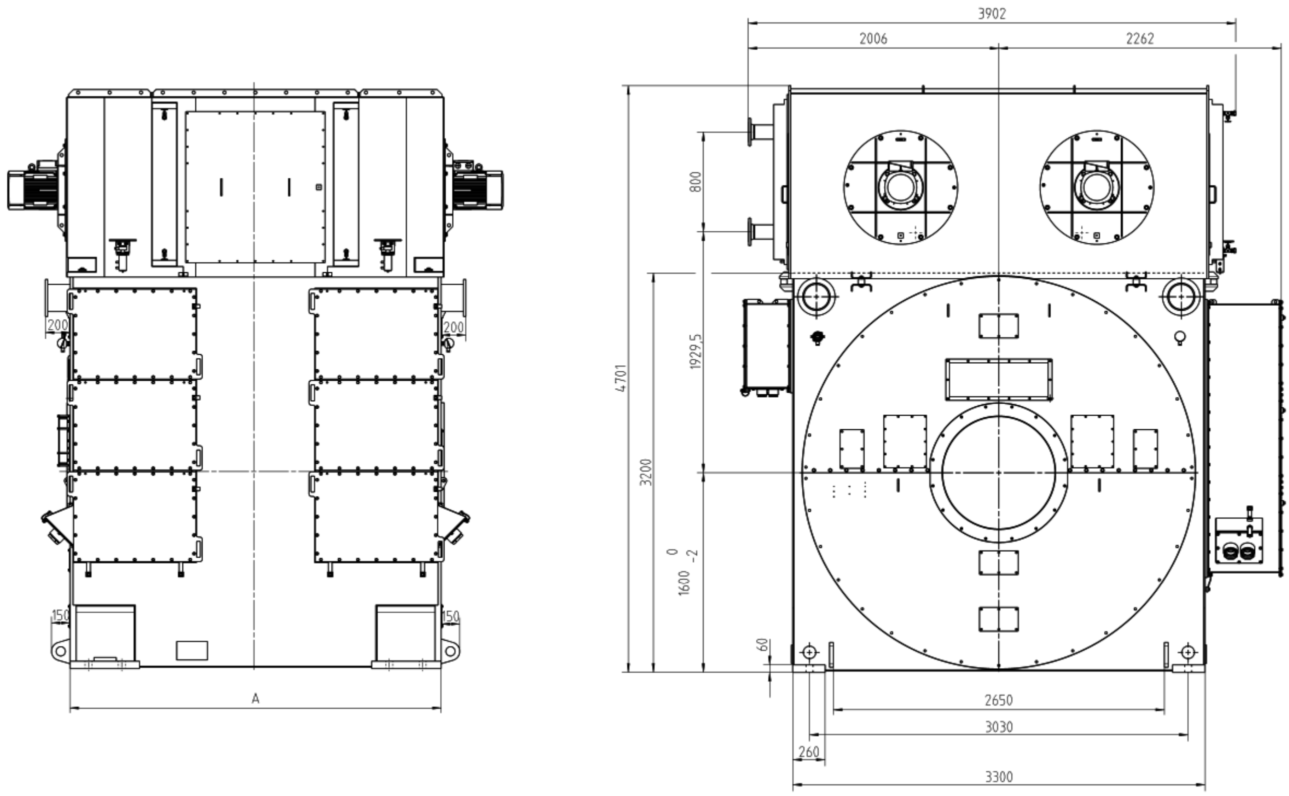
8.3.4 Shaft height 1600 mm, up to type 1650



Type	A	B	C	D	E	F	G	H	Gewicht ohne Rotor [kg] ± 5%
D_MU_ 1632-___	2320	1025	1295	605	875	146,5	721,5	700	29600
D_MU_ 1636-___		1085	1235	665	815	86,5	661,5		31060
D_MU_ 1640-___		1145	1175	725	755	26,5	601,5		32500
D_MU_ 1645-___	2620	1220	1400	800	980	251,5	826,5		35000
D_MU_ 1650-___		1295	1325	875	905	176,5	751,5		36570

8.3.5 Shaft height 1600 mm, as of type 1656

The machines of this length are equipped with two water coolers in the cooler housing for a 2 -flow air circuit in the cooler housing.



Type	A	Gewicht ohne Rotor [kg] ± 5%
D_MU_ 1656-___	3010	39200
D_MU_ 1663-___		41580
D_MU_ 1671-___	3250	44000

9 Literature and picture credits

[1] IEC 60034-1

[2] IEC 60034-18

[3] VEM publication "Permanent heat resistance of the insulation system VEMoDUR-VPI-155".

[4] IEC 60034-15

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