TESU
Brushless Constant-Voltage Synchronous Generators

for industrial, shipboard and hydro power plant use
Brushless constant-voltage synchronous generators

The Brushless Constant-Voltage Synchronous Generators are the result of our experience for some decades.

Explanation of generator type design

The example below shows what the generator type design mean

**TNC9 802 8**

*TNC9* indicates the generator family.

When the letter J (*TNJ9*) stands instead of the letter C it means that the generators with protection degree IP44, IP45, water cooled i.e. provided with closed cooling system With built-in single tube or double tube water / air cooler here involved.

*802* indicates the generator size (in B3 version it means that height from the generator support to the shaft centerline is 800 mm)

*8* is number of poles (4 means 4 poles, 6 means 6 poles, 8 means 8 poles, 3 means 10 poles and 5 means 12 poles)

**Rating**

<table>
<thead>
<tr>
<th>Mounting form</th>
<th>1FC(J)</th>
<th>1VC(J)</th>
<th>TNC(J)9</th>
<th>TVC(J)9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poles number</td>
<td>4 - 12</td>
<td>4 - 12</td>
<td>4 - 12</td>
<td>4 - 12</td>
</tr>
<tr>
<td>Power output</td>
<td>145 – 5200 kVA</td>
<td>145 – 5200 kVA</td>
<td>900 – 7000 kVA</td>
<td>900 – 7000 kVA</td>
</tr>
<tr>
<td>Voltage</td>
<td>400 – 900 V</td>
<td>400 – 900 V</td>
<td>4.16 kV – 13.8 kV</td>
<td>4.16 kV – 13.8 kV</td>
</tr>
<tr>
<td>Frequency</td>
<td>50 Hz, 60 Hz</td>
<td>50 Hz, 60 Hz</td>
<td>50 Hz, 60 Hz</td>
<td>50 Hz, 60 Hz</td>
</tr>
<tr>
<td>Sizes</td>
<td>280 – 800</td>
<td>280 – 800</td>
<td>560 – 800</td>
<td>560 – 800</td>
</tr>
<tr>
<td>Weight</td>
<td>710 – 15000 kg</td>
<td>900 – 17500 kg</td>
<td>4400 – 16670 kg</td>
<td>5300 – 20000 kg</td>
</tr>
</tbody>
</table>

More poles as a smaller or higher nominal powers available on special request.
Brushless constant-voltage synchronous generators

Application

All TESU generators can be used as main or standby units in land based power installations, or can be used for ship’s electrical systems. Internal combustion engines or gas steam and water turbines and electric motors can drive them.

Construction

The TESU synchronous generators are low and/or high-voltage machines. The generator comprises the main machine, exciter and excitation unit. The brushless constant-voltage synchronous generators are of the self-excited type with an automatic voltage regulator. The generators are designed for self-ventilation.

Frame and stator core

The stator consists of the housing with the core and windings for the main machine, exciter, end shields and bearings. The generators are fitted with top mounted excitation control unit or it is mounted separately in a box.

The housing is made of steel plate. The mounting feet, which are an integral part of the housing, are designed depending on the type of construction.

The output voltage terminal box may be fitted on side of the housing. The terminal box is spacious and readily accessible permitting easy and reliable connection of the cables. It is designed for degree of protection IP54.

The stator core of the main machine is made of high quality both sides insulated electrical sheet steel. It is subdivided into stacks by means of ventilating ducts and spacers thus ensuring effective cooling. The complete core with windings is pressed into the housing.

The exciter housed in the same generator housing is mounted on the end shield at the non-drive end.

The end shields of welded structure carry the rolling or sleeve bearings assembly.

Main stator winding

The stator windings are made applying the most recent developments in engineering and materials. Uljanik-TESU for it's generators utilise several different insulation systems depending on voltage rating. This insulation is featured by high percentage of mica.

Conductors are insulated with varnish and double layer of glass fibre of high dielectric strength. Mica type coil insulation is used. The insulation is baked under pressure so to completely eliminate air and to obtain a homogenous layer. The winding end turns are insulated with polymerised mica tape, which simultaneously gives both dielectric strength and elasticity. The final layer protects the insulation against detrimental atmospheric and chemical influences.
**Brushless constant-voltage synchronous generators**

Selected material and method of binding result in a strong and unified winding assembly that will withstand the large mechanical forces which appear during different generator transient fault conditions (sudden short-circuits, loss of synchronism).

**Cylindrical rotor**

The rotor is laminated, cylindrical. The windings are placed in the semi-closed slots. They are impregnated with solvent-free resin. Such design offers the excellent mechanical properties. The rotor is fitted with a complete cage serving as damper winding.

The rotor consists of the shaft, the rotor core, the field and damper windings. The shaft also carries, on the non-drive end, the rotating rectifier, the rotor core of the exciter with a three-phase winding. The shaft is fitted with fan.

The rotor core of the main machine is made of electrical non-oriented sheet steels. Ventilating ducts, which are formed by spacers, subdivide the core into packets and ensure effective cooling.

The field winding is arranged around the core periphery. The winding is distributed over slots per pole, which ensures that the rotating masses are uniformly distributed over the rotor circumference. Therefore the mechanical stressing due to the centrifugal forces is considerably smaller. In addition to this, a uniform temperature distribution is thereby obtained, which increases the life of the winding. To make the end turns resistant to the centrifugal forces, rings of fiberglass are fitted on the overhang. For the slot insulation of rotor winding the Nomex material is used. All the connections of the winding are hardsoldered. The rotor core assembly with winding is impregnated with resin.

The damper winding consists of bars, which are accommodated in equally spaced slots. At the core ends, the bars are bent and welded to end rings, thus forming a damper cage. With synchronous machines the damper winding reduces distortion of the voltage and current waves to a minimum, even under conditions of unbalanced loading. Owing to the good magnetic coupling between the stator and damper winding the effects of inducing disturbances, such as torque pulsation, which occur in some driving machines, electrical and mechanical shock loads and harmonics are effectively suppressed.

The rotating rectifier comprises a full-wave three-phase rectifying bridge. The rectifier design and selected high-quality silicon elements ensure high operation safety and protect the diodes.

The thermal endurance of the winding insulation of the main machine and the exciter satisfies the requirements for class F insulation. The insulation is resistant to moisture, oil vapours and sea air.
Brushless constant-voltage synchronous generators

Excitation system

The mode of operation of excitation system is compound. The main stator supplies the exciter via excitation unit. The voltage regulator regulated the field current necessary to obtain constant generator voltage.

Mode of operation

The rotating excitation winding of the generator itself is supplied from the rotor winding of the exciter via rotating diodes in three-phase bridge connection. The stationary field winding of the exciter is supplied from the stationary excitation system. When the generator is driven, the remanent magnetism of the active iron in the stator core of the main machine produces a speed-dependent self-excitation voltage. Part of the energy thus produced is trapped of the generator terminals and taken to the field winding of the exciter via the excitation control unit. This completes the circuit in which the excitation energy flows.

The excitation control unit adds up an generator-voltage-proportional component and an generator-current-proportional component to form an excitation current slightly higher than necessary to produce the rated voltage. The thyristor voltage regulator then keeps the generator voltage at the required level by allowing the excess excitation current to flow in a bypass to the excitation winding (buck control).

The generator excitation current is controlled at a low energy level.

Standards and Requirements

The generators conform to applicable IEC requirements, DIN standards and VDE codes and particularly to VDE 0530, Specification for rotating electrical machines. They can also be made to comply with foreign standards and requirements.

BS 2613 and 5000 part 16,
NF C51-100,
CSA C22.2-100
CEI 2-3
Other standards on enquiry

The excitation equipment has been rated for compliance with Group C requirements to VDE 0660 and VDE 0110.
Technical data

Output
The rated outputs (kVA) are valid for following operating conditions:
- continuous running duty at 50 or 60 Hz rated frequency
- power factors from 0.8 to 1,
- class F insulating
- sinusoidal load current
- symmetrical load

Site rated output
The application and site conditions for the correct sizing of generator should be taken into consideration.
The following factors should be taken into consideration:

1. Ambient temperature
The generators are designated for use under 40°C ambient temperature.
If coolant temperature exceeds 40°C, then reduced ratings according to standard or classification society rules should be taken into consideration.
The output rating can be obtained by applying the factors as in the following table.

<table>
<thead>
<tr>
<th>Ambient Temperature [°C]</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiply by factor</td>
<td>1.00</td>
<td>0.95</td>
<td>0.925</td>
<td>0.9</td>
</tr>
</tbody>
</table>

2. Altitude
The generators are designated for use in altitude less than 1000 m.a.s.l.
In case altitude exceeds 1000 m a.s.l. then generator reduced ratings should be taken into consideration (does not apply for marine generators).

<table>
<thead>
<tr>
<th>Site altitude m.a.s.l.</th>
<th>Permissible output % of rated value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>100</td>
</tr>
<tr>
<td>1500</td>
<td>97</td>
</tr>
<tr>
<td>2000</td>
<td>94</td>
</tr>
<tr>
<td>2500</td>
<td>91</td>
</tr>
<tr>
<td>3000</td>
<td>87</td>
</tr>
<tr>
<td>3500</td>
<td>82</td>
</tr>
<tr>
<td>4000</td>
<td>77</td>
</tr>
</tbody>
</table>

If no coolant temperature is stated, it will be assumed that the altitude-induced reduction in the cooling efficiency is compensated by a lower coolant temperature. i.e. that adjustment of the maximum temperature rise to VDE 0530 is not necessary (no derating).
The following coolant temperatures are obtained for the thermal utilization corresponding to Class F insulation:

Altitude in m a.s.l: 1000, 1500, 2000, 2500, 3000, 3500, 4000
Coolant temperature in °C: 40, 35, 30, 25, 19, 14, 9
Technical data

3. Power factor cos φ < 0.8

If power factor is less than 0.8 then reduced ratings should be taken into consideration.

<table>
<thead>
<tr>
<th>Cos φ</th>
<th>Permissible output % of rated value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8 ... 1</td>
<td>100</td>
</tr>
<tr>
<td>0.7</td>
<td>96</td>
</tr>
<tr>
<td>0.6</td>
<td>92</td>
</tr>
<tr>
<td>0.5</td>
<td>91</td>
</tr>
<tr>
<td>0.4</td>
<td>90</td>
</tr>
<tr>
<td>0.0</td>
<td>88</td>
</tr>
</tbody>
</table>

Voltage and frequency

The generators are available for 50 Hz or 60 Hz.

Rated voltages of generators are between 400 V and 13.8 kV.

The rated voltage can be standard adjusted within a range of ±5%. Other voltage adjustment ranges are possible on request.

Enquires are also welcomed for special voltages and for frequencies other than 50 and 60 Hz.

Apart from an internal reference value potentiometer on the regulator the rated voltages can be adjusted ±5% using an external panel mounting reference value setter (optional extra).

The three-phase stator winding of the generators is connected in star. The neutral point is brought out.

Radio interference suppression

The generators are supplied with interference suppression grade N to VDE 0875, suppression level K on request.

Special measures

Special insulation design can be delivered where extreme exposure to water, e.g. due to flooding or prolonged condensate formation, or high concentrations of aggressive or electrolytically active media are to be expected. (Please enquire for further information).
A1  Voltage regulator
C1…C3  Capacitor
G1  Main machine
G2  Exciter
L1  Reactor
T1…T3  Single phase current transformer
T4  Current transformer for droop compensation
T6  Rectifier transformer
T7…T8  Voltage transformer
V1  Stationary rectifier
V2  Rotating rectifier
**Types of construction**

The generators can be available in the versions according to IEC 34-7. They can be two bearing or single bearing designed. Depending on operating conditions and technical limits of bearing, generator can be available with rolling contact bearings or sleeve bearings.

**Degree of protection**

The generators normally have degree of protection IP 23 (DIN 40 050). The terminal box has degree of protection IP 54. Other degrees of protection are available on request.

**Speed and direction of rotation**

The generator speed is defined to meet the requirements of the prime mover. At the rated speed the generator produces the rated frequency of 50 Hz or 60 Hz. The generators are made for clockwise or anti-clockwise running when viewed from the drive end.

Overspeed for generator is $n_{\text{max}} = 1.2 \times n$

Higher values are possible on request.

**Air filter**

An air filter can be fitted for special conditions (on request).

**Anti-condensation heating**

Anti-condensation heating is available for the generators (on request). The anti-condensation heater requires a voltage of 220 V or 110V and has heat output of about 315 W to 630W:

**Terminals and connection bus-bars**

Main terminal box is available with one terminal box which comprises 4 main connections, (U, V, W, N) or two terminal boxes which comprise 6 main connections (U1, U2, V1, V2, W1, W2).

**Paint finish**

The generators are supplied with a priming coat. Standard paint finish in RAL 7030 or other colours or special paint finish can be provided at extra cost.
Cooling

The generators are internally air cooled by shaft-mounted fan (IC 01). The fan provided at the drive-end draws the cooling air axially through the machine.

Drive and coupling

The generators provided with two bearings can be driven by reciprocating engines via flexible shaft couplings. The coupling is not part of the scope of delivery of the generator manufacturer. The torsional vibration has to be calculated for rigidly coupled single-bearing generators. For this purpose, a preliminary generator and shaft dimension sheet is made available.

Types of construction

The generators can be supplied in the following versions to IEC 34-7. IM = international mounting. DIN 42 950 designations are in brackets.

For information about the different types of construction with extra or reduced prices refer to the price list or please enquire.

Generators sizes 284 to 354 can be easily adapted to various mounting situations by the feet mountings on the housing. They can also be supplied without feet (reduced price).

If requested, flange dimensions other than those quoted in the dimensions tables can be supplied (extra price). Please give flange diameter N and flange depth R.
Performance data

Behaviour under steady-state conditions

The generators in the new range are particularly good at meeting the requirement for stable voltage control throughout the load range. The steady-state deviation from the rated voltage is not greater than 0.5% anywhere in the range from no-load to full load. The usual speed increase of the prime mover on change over from rated load to no load does not affect the accuracy stated. The setpoint potentiometer included in the voltage regulator or an external panel-mounting potentiometer permits the generator voltage to be adjusted within a range of ±5% of the rated voltage. In the event of faults in the regulating system, the generator voltage never rises beyond 115% of the rated voltage owing to the buck control principle adopted for the excitation system. The excitation system can supply a sustained short-circuit current of three to five times the rated current; this enables the use of graded protective relaying.

A speed-proportional voltage is produced during run-up of the generator from the nonexcited condition or during operation at less than rated speed and the excitation current does not rise beyond the permissible values. This precludes the risk of thermal damage to the excitation winding even at less than rated speed.

Dynamic behaviour

The excitation system and a carefully matched electromagnetic design of the main and exciter machines together make for highly satisfactory dynamic voltage control behaviour. With the phase shift between the current and voltage corresponding to 0.8 p.f. the transient voltage reduction or increase on connection or disconnection of rated load is only about 15%. This value is largely determined by the subtransient reactance of the main machine, i.e. by the leakage inductance of the windings. The settling time is shorter than 500 ms. With the command variable (load current) closely coupled to the output variable (excitation current) by compound excitation, this generator responds to sudden load changes much faster than a generator with ordinary closed-loop control. Because in the excitation system the controller only needs to correct the difference between the setpoint value and the value defined by compounding, the favorable effect of compounding is retained in full.

Parallel operation

Stable parallel operation is ensured by:

- damper winding, which counteracts phase swinging,
- the quadrature-droop device included in the excitation control unit to ensure equal reactive-load sharing and,
- the setting of the speed controllers of the prime movers for appropriate sharing of the active power, this being within the sphere of responsibility of the supplier of the prime movers.
The quadrature-droop device consists of a current transformer and a droop potentiometer included in the voltage regulator. A reactive current dependent voltage is added to the voltage signal representing the actual generator voltage. This addition to the actual-value voltage causes the voltage regulator to linearly reduce the generator voltage by a preset droop percentage in a manner depending on the reactive current output. At zero power factor and rated power the voltage reduction amounts to 6% of the rated voltage. With the same voltage droop settings the generators thus equipped can be operated in parallel without any limits set by the reactive load sharing and by the risk of phase swinging.

**Unbalanced Load**

The generators can withstand unbalanced loading of up to 20%.

**Overload**

In accordance with IEC 34-1, the generators can have an overload of 1.5 times the rated current at rated voltage for 30 sec.

**Sustained short-circuit current**

The excitation unit used is designed to withstand a sustained three-phase short-circuit current of 3 to 5 times the rated current for a period of 3 seconds. This enables the use of selective protection systems.

**Generator protection equipment**

The stator winding can be provided with thermal protection in the form of PTC sensors or resistance thermometers PT 100 (on request) The necessary monitoring and tripping devices must be provided separately and are not included in the generator scope of supply.
Special provisions for marine generators

In addition to satisfying the standards and codes the marine generators also conform to the requirements of the following classification societies:

<table>
<thead>
<tr>
<th>Classification society</th>
<th>Abbreviation</th>
<th>Coolant temperature (CT) °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Bureau of Shipping</td>
<td>ABS</td>
<td>50</td>
</tr>
<tr>
<td>Bureau Veritas</td>
<td>BV</td>
<td>40, 45, 50</td>
</tr>
<tr>
<td>Germanischer Lloyd</td>
<td>GL</td>
<td>40, 45</td>
</tr>
<tr>
<td>Lloyd's Register of Shipping</td>
<td>LRS</td>
<td>40, 45, 50</td>
</tr>
<tr>
<td>Det Norske Veritas</td>
<td>NV</td>
<td>35, 45</td>
</tr>
<tr>
<td>Registro Italiano Navale</td>
<td>RINa</td>
<td>45, 50</td>
</tr>
</tbody>
</table>

Marine generators can also be supplied to satisfy the requirements of other classification societies such as:

- Polski Rejestr Statkow PRS
- USSR Register of Shipping
- U.S.Coast Guard
- Register of Shipping of P.R. of China

With generators to be operated as shaft generators (driven from the main engine or turbine) attention must be paid to the special speed characteristic and, if applicable, to the excess-torque protection. Please enquire for further information.

**Works inspection and acceptance**

All marine generators are subject to works inspection and acceptance as stipulated in the Table below:

<table>
<thead>
<tr>
<th>Classification society Abbreviation</th>
<th>Works inspection</th>
<th>Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS</td>
<td>≥100 kW</td>
<td>≥100 kW</td>
</tr>
<tr>
<td>BV</td>
<td>≥100 kW</td>
<td>All</td>
</tr>
<tr>
<td>GL</td>
<td>-</td>
<td>≥50 kW</td>
</tr>
<tr>
<td>LRS, RINa</td>
<td>≥100 kW</td>
<td>≥100 kW</td>
</tr>
<tr>
<td>NV</td>
<td>all</td>
<td>all</td>
</tr>
</tbody>
</table>

Generators intended for use on a ship's propulsion system are subject to works inspection and acceptance testing, irrespective of the output rating.
Special provisions for marine generators

Overload requirements

<table>
<thead>
<tr>
<th>Rules</th>
<th>Overload current</th>
<th>Overload duration</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDE</td>
<td>150</td>
<td>2 min</td>
<td>-</td>
</tr>
<tr>
<td>ABS</td>
<td>-</td>
<td>-</td>
<td>no overload capability specified only at owner’s request. Steady-state temperature Rise from previous operation not to be more than 15K</td>
</tr>
<tr>
<td></td>
<td>125</td>
<td>2 h*)</td>
<td></td>
</tr>
<tr>
<td>BV</td>
<td>150</td>
<td>2 min</td>
<td>at p.f. 0.6 (lagging)</td>
</tr>
<tr>
<td>GL</td>
<td>150</td>
<td>2 min</td>
<td>at p.f. 0.5 (lagging)</td>
</tr>
<tr>
<td>LRS</td>
<td>150</td>
<td>15 s</td>
<td>-</td>
</tr>
<tr>
<td>NV</td>
<td>150</td>
<td>2 min</td>
<td>Only for Alternators At p.f. 0.6 and rated frequency</td>
</tr>
<tr>
<td>RINa</td>
<td>150</td>
<td>2 min</td>
<td>at p.f. 0.6 (lagging)</td>
</tr>
</tbody>
</table>

During overload the voltage must be kept as nearly as possible at its rated value.

*) The rated output given in the Selection Tables is to be reduced to 88 %.

Air/water cooler

If required, the generators can be supplied with a top-fitted air/water cooler. The cooler can be used for freshwater or salt water and can be of the single-tube or double-tube type.

The type designation for the generators is changed from 1FC to 1FJ. Due to the closed-circuit cooling system the degree of protection has been upgraded from IP 23 to IP 54. The electrical version of the generator remains unchanged.

The generators 1FJ can easily be converted for emergency operation as an open-circuit aircooled machine if the coolant system or the cooling element fails. In this case, the degree of protection is IP 23 with the rated output unaltered.

The rated output of the generator type chosen thus corresponds to the values in the Selection Tables with the associated coolant temperature. Please provide the following information with any enquiry:
- Generator rated output
- Classification society
- Coolant temperature (air)
- Cooling water inlet temperature
- Freshwater or seawater
- Single-tube or double-tube cooler

The exact dimension of the cooler and the height of the generator will be defined in case of order.
Special provisions for marine generators

Classification society rules

<table>
<thead>
<tr>
<th>Classification Society</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABS</strong></td>
</tr>
<tr>
<td>GL</td>
</tr>
<tr>
<td>LRS</td>
</tr>
</tbody>
</table>

| | • Thermometer |
| | • Temperature sensor |
| ABS | Resistance thermometer to measure the stator winding temperature for generators above 500 kVA |
| GL | Temperature sensors in the stator winding for generators with air filters; thermometer in the cooling air circuit and a temperature sensor in the stator winding for generators with air/water cooler; bearing thermometer for sleeve bearings; alarm device for excessive temperature of bearings with external lubrication. |
| LRS | Temperature sensor in the cooling air circuit for generators with air/water cooler |

*) We always recommend that generators for emergency and port use be ordered with anti-condensation heating, regardless of the classification society rules.

Spare parts

Classification societies generally call for the following spare parts:

<table>
<thead>
<tr>
<th>Spare parts</th>
<th>Classification society</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 set rolling-contact bearings (bearing shells for sleeve bearings)</td>
<td>•</td>
</tr>
<tr>
<td>1/3 rectifier assembly</td>
<td></td>
</tr>
<tr>
<td>1 electronic voltage regulator</td>
<td>•</td>
</tr>
<tr>
<td>1 set brush holder</td>
<td>•</td>
</tr>
<tr>
<td>1 set brush spare parts</td>
<td>•</td>
</tr>
<tr>
<td>1 set of special tools</td>
<td>•</td>
</tr>
</tbody>
</table>

Regardless of the requirements made by the classification societies we recommend that the spare parts be ordered together with the generators.