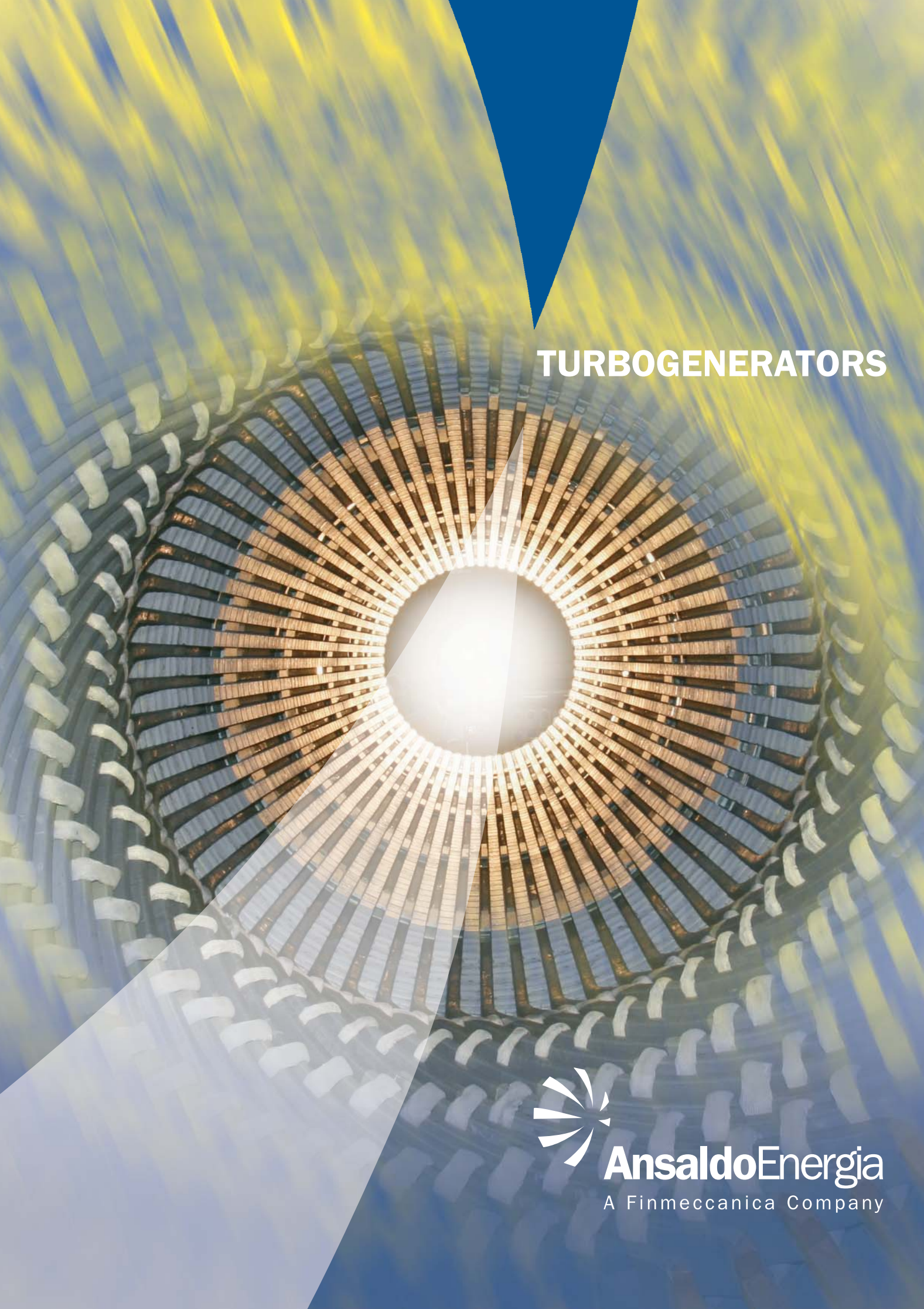
TURBOGENERATORS



AnsaldoEnergia
A Finmeccanica Company

Turbogenerators

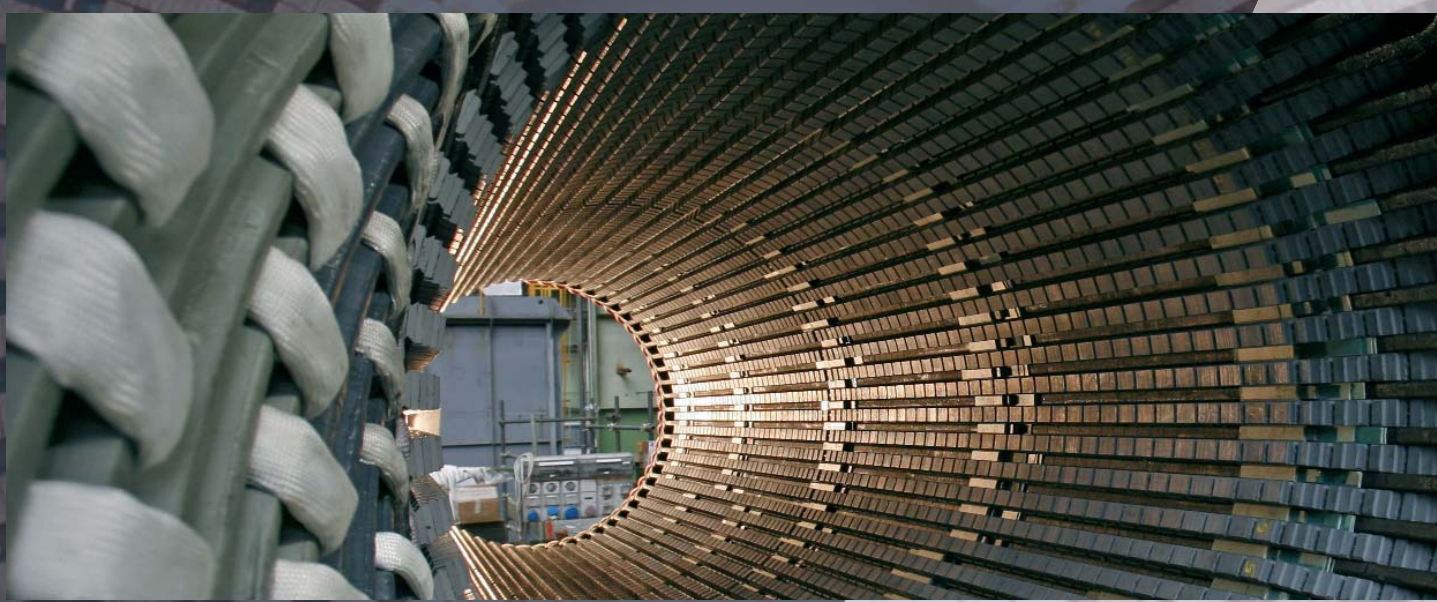
Ansaldo Energia produced its first air-cooled turbine generators in the early 1920s.
Since 1950 about 500 units in the 10 to 330 MVA range have left the Genoa production facility for installation worldwide.
Ansaldo Energia also has extensive experience in the design and construction of hydrogen and hydrogen-water cooled turbogenerators.
More than 200 units in the 40 to 1,220 MVA range have been manufactured over the last forty years.
The global installed generating capacity is over 100,000 MVA.

Air-Cooled Turbogenerators

Air-cooled turbogenerators provide a modern, highly compact solution for:

- base and peak load operation
- daily startup and shutdown
- easy, low cost maintenance

A range of models offering high efficiency, excellent quality and optimum reliability are available to meet prime mover requirements.



AIR COOLED TURBOGENERATORS - GENERAL CHARACTERISTICS

Generators have indirect cooled stator windings and direct cooled rotor windings.
Stator core is direct cooled with air.

Frequency Hz	Speed RPM	Power factor	Rated Voltage kV	Power Range MVA
50	3000	0,8	10,5 - 16	20 - 210
50	3000	0,8	15 - 19	210 - 350
60	3600	0,85	13,8 - 18	30 - 230
60	3600	0,85	17 - 21	230 - 300

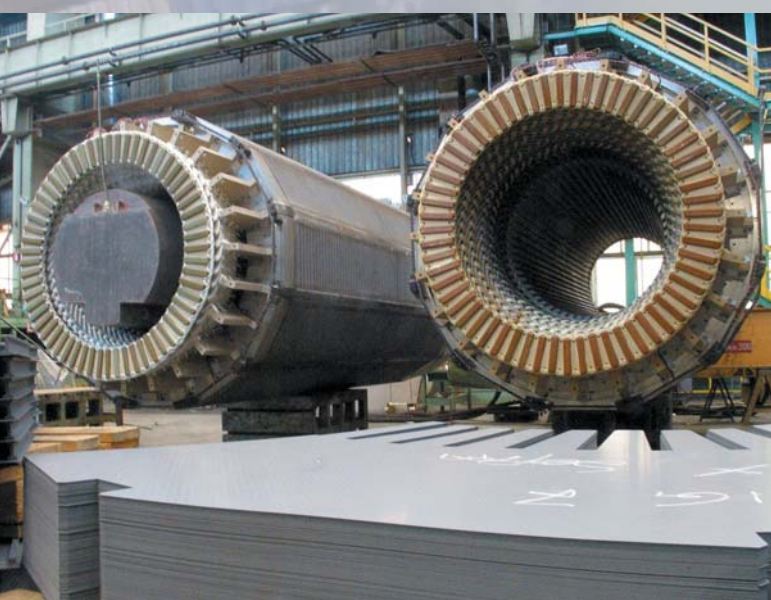
- Mounting arrangement:	IM7305, IM7315, IM7316
- Method of cooling:	IC 9 A1 W7 - IC 8 A1 W7
- Protection degree:	IP 54 (IEC 60034-5)
- Excitation:	static (standard) or brushless as special application
- Terminal insulation class:	F; thermally loaded only to class B
- Terminal location:	• above 3 + 3 • below, for connection to the bus duct in the foundation in the lower part of the frame in the foundation
- Coolers arrangement:	• in the lower part of the frame • in the foundation
- Installation:	with soundproof en closure for indoor or outdoor application

Reliability

CAD/CAM technology is applied extensively in the design and manufacturing process to improve flexibility in satisfying customer requirements and reduce workshop construction time.
All generators are designed around tried and tested standard components.
The machinery is designed for continuous operation and faults like sudden short circuits are handled without damage.
Most sophisticated operation plans can be realised in our modern manufacturing facilities covered by an efficient Quality System organisation.
Our comprehensive, reliable after-sales service is reviewed regularly to assimilate operating experience.
Product oriented R&D guarantees constant, gradual evolution in line with customer needs

Design features and manufacture

Ansaldo Energia air-cooled generators have indirectly cooled stator windings and directly cooled rotor windings.
Generators are self-ventilated in a closed circuit with air to water coolers.
Special make-up or active-carbon filters can be provided if needed for reasons of air contamination.
Direct cooling ensures limited temperature levels over the entire rotor winding.
The stator comprises the two bolted frame sections horizontally splitted, the assembled stator core and the winding. Splitting the frame into sections speeds up generator delivery and facilitates stator maintenance operations. The stator core comprises numerous lamination packets fabricated from high quality magnetic silicon steel sheets coated on both sides with class F insulating varnish. The core is cooled by air passing through radial ducts between lamination packets.



The self-supporting stator core is assembled and welded to the lower part of the housing in such a way as to permit thermal expansion and core vibration without transmission to the foundation.
The stator has a two-layer transposed bar winding insulated with mica paper on glass-fibre tape.
The stator winding is class F insulated with single bar insulation system. For smaller units only, alternative insulation system with the entire wound stator core impregnated under vacuum with solvent-free epoxy resin is available when specifically required.

After curing, the insulation meets all class F requirements as well as having excellent long-term in-service durability and outstanding mechanical and electrical properties. Conductive varnish and tapes prevent corona discharges between the insulation and the slot wall or in the end region.

Bars are firmly braced in the slots by means of epoxy-glass slot wedges and a ripple spring to prevent loosening after long service. The rotor body is machined from a single alloy steel forging with excellent magnetic and mechanical properties. Forgings are comprehensively inspected by sampling and ultrasonic testing. Purchasing specifications include heat treatment quality after reforging, residual stresses and surface finishing. Appropriate tests are performed to ensure compliance to specifications. The mechanical and magnetic properties of forgings are tested at the supplier's workshop.

The rotor winding consists of hollow rectangular conductors made of hard-drawn copper alloyed with silver to increase strength at operating temperature.

The rotor winding can expand uniformly lengthwise to ensure smooth running and minimum sensitivity to rapid load changes. All the insulation materials used in the rotor comply with class F specifications.

The rotor surface is protected against circulating currents caused by unbalanced loads through special high conductivity wedges and short circuit rings under retaining rings.

The retaining rings hold the rotor end winding in place and are manufactured from high strength non-magnetic steel (18-18 Cr Mn) which offers the best solution to stress corrosion cracking.

One end of each ring is shrunk-on to the rotor body in a cantilever configuration. The cooling air flow through the machine is provided by two axial fans, one at each end of the rotor. The rotor is supported by two bearings with white metal bushes carried in bearing pedestals.

Excitation system

Standard solution consists of fully static excitation system which comprises an excitation power transformer, a power converter with controls and protections, a static circuit breaker and, for excitation systems connected to generator terminals, a startup excitation from plant DC batteries.

Transport

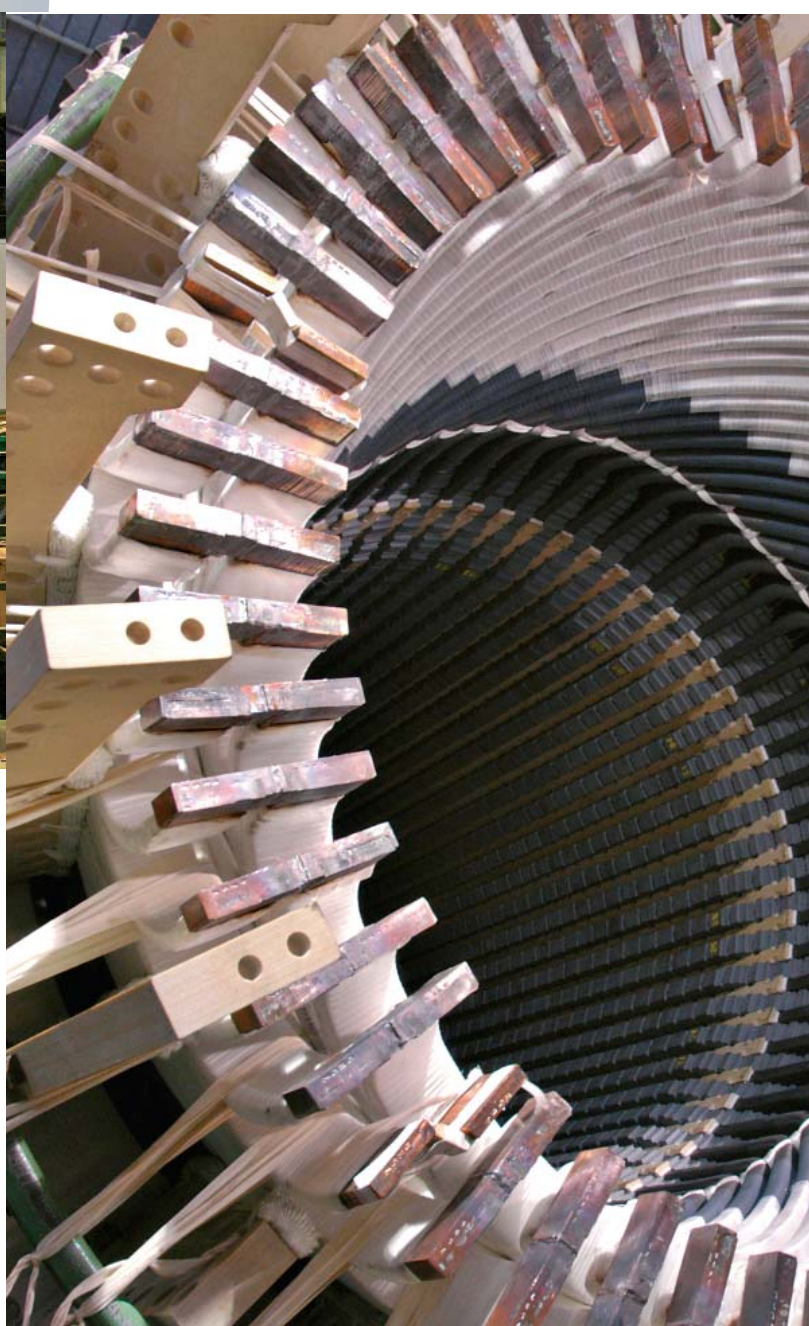
The overall dimensions of generators comply with rail transport limits.
Generators for gas turbines can be transported in assembled form, reducing shipment costs and simplifying on-site erection and alignment work.

Testing

All generators are subjected to a standard program of tests including:

- stator core magnetization
- winding resistance
- insulation resistance
- impedance measurement
- high potential
- mechanical rotor balance and rotor overspeed.

Running tests and special tests can be performed on request. All tests are performed in compliance with IEEE and IEC standards.

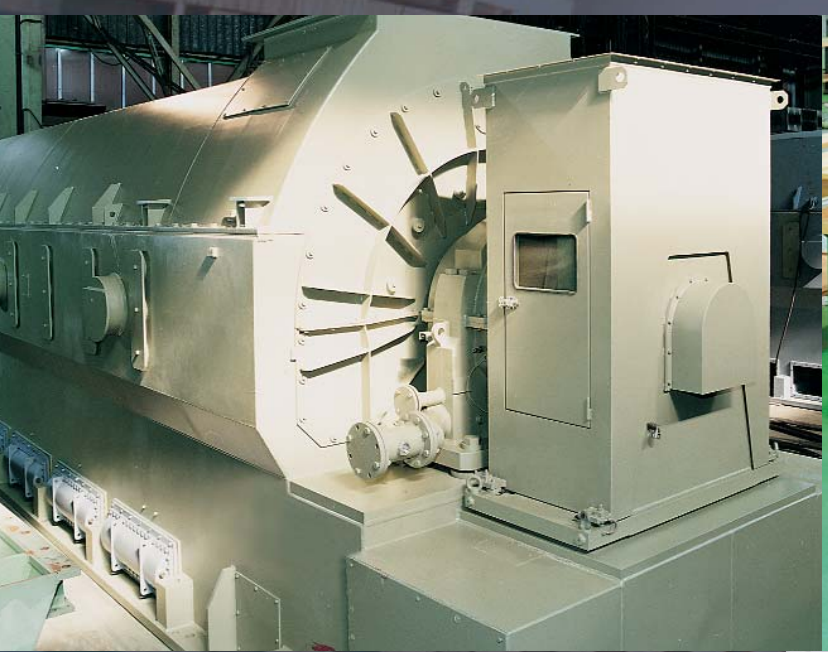


Hydrogen cooled/Hydrogen and stator water cooled turbogenerators

Design features and manufacture

The stator frame is a welded steel fabrication with sufficient strength to contain the internal pressure exerted by the hydrogen gas. In reality, for safety reasons, it is designed to withstand an internal explosion.
The stator core is fabricated from low-loss silicon alloy magnetic steel sheet laminations.
Individual segments are punched, de-burred and coated on both sides with heat resistant varnish.
The core is pressed at intervals during stacking and finally consolidated to ensure that individual laminations don't loosen during service.
All generators with water-cooled stator windings are fitted with laminated pressplates to reduce losses and eliminate hotspots. Two pole generators are fitted with radially flexible intermediate members which decouple the housing and foundation from double-frequency core vibrations.

The core is cooled by hydrogen gas flowing in radial ducts. In generators with water-cooled stator windings the core is cooled axially.
The standard stator winding design is the double-layer Roebel bar. The two bars in each slot are separated by an insulating spacer and firmly braced in the slot by wedges.Slot forces during operation and transients, forces due to thermal expansion and the long-term behaviour of the insulation, are factored into the design and construction processes.
In water-cooled windings, hollow non-magnetic stainless steel conductors are transposed together with solid conductors to form bars.
Resin rich tape is used to insulate the main bar insulation, with single bar VPI impregnation adopted for large generators with water-cooled stator winding.
Conductive varnish ensures uniform potential at the bar periphery after installation and a corona-protection system provides stress potential grading in the overhang region. The finished insulation meets class F requirements.



Forces generated during sudden short circuits are restrained by heavy rings used as the basic support.
In smaller units solid outer rings are sufficient for this purpose. On large generators the end windings can easily be checked for tightness during overhauls using a torque wrench with access through the manholes.
This guarantees uniform stiffness of the end winding throughout operating life. Differential thermal expansion is accommodated by means of an elastic end winding suspension.
This makes these generators particularly suited to variable load operation or frequent starting and stopping.
The rotor body is a single heat-treated forging with high strength and high magnetic permeability.
The coupling flanges at each end (to the turbine and to the exciter or slip ring shaft respectively) are integral parts of the forging.
The centrifugal forces caused by the rotor winding and slot wedges are borne by the rotor teeth in the active part of the rotor.
Centrifugal forces from the end winding in the end part of the rotor are borne by its retaining rings.
The rings are made of high-strength non-magnetic steel (18 Mn 18 Cr) which offers the best solution to stress corrosion cracking. The rotor winding is manufactured from silver alloy copper which has a higher yield strength than normal non-alloyed copper. It also has the fatigue strength needed to withstand the high mechanical stress to which the rotor winding is subjected.
The slot walls are insulated using continuous U profiles with high mechanical and dielectric strength.
The winding in the end zone is insulated from the rotor retaining ring by several layers of insulation (glass epoxy or aramid paper).
All insulation materials comply with class F requirements. Generators are provided with a winding the damper system designed to damp out rotor swings after sudden load changes. It also prevents excessive rotor surface heating when the three phases are asymmetrical. Rotor winding is directly cooled by coolant gas which flows inside the rotor conductors. Cooling gas flow through the machine is provided by fans shrunk onto the shaft. Two axial fans, one on each rotor end, are used in hydrogen cooled machines, while in largest generator (water-cooled stator winding) one radial fan is foreseen.

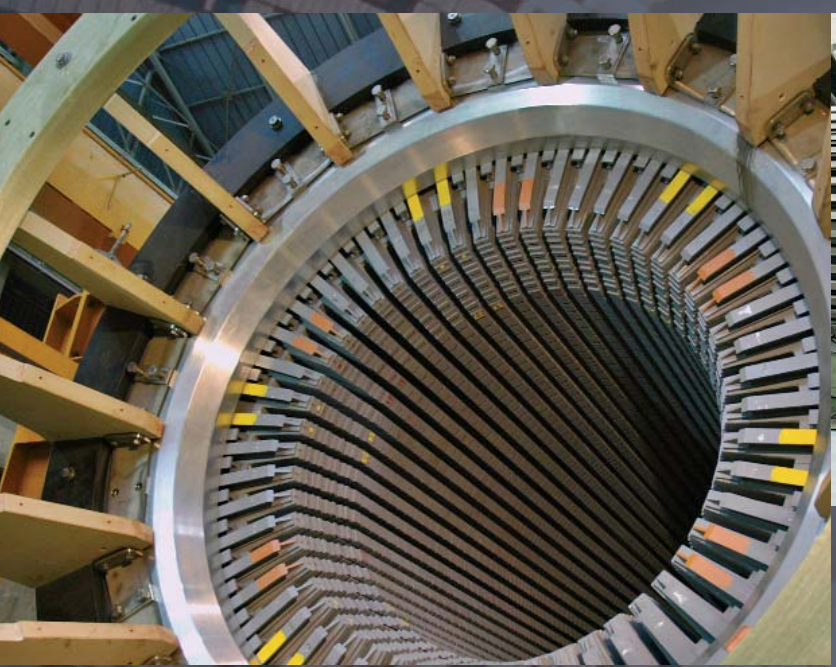
Auxiliary systems

A number of auxiliary systems are needed to condition and circulate the water and hydrogen used for cooling and keep the shaft seals supplied with oil.
The gas plant conditions and monitors the coolant under all operating conditions. Its main functions are:

- to drive out air with an inert gas (CO_2)
- to drive out inert gas with hydrogen
- to add hydrogen to maintain the correct pressure
- to drive out hydrogen with inert gas
- to drive out inert gas with air.

Larger generators have water-cooled stator windings, terminal bushings and winding connections.

The stator cooling-water plant conditions, circulates and monitors the cooling water (neutral water with very low oxygen content and electrical conductivity).
It is therefore provided with oxygen removal and deionisation equipment plus all the necessary pumps and filters.
When hydrogen is used as coolant, shaft seals are implemented by oil flowing into the gap between the shaft and suitable rings.
The seal oil plant comprises the equipment needed to supply oil to the shaft seals at the right temperature, pressure and purity.



Excitation system

To deliver stable power supply when operating on a network and maintain generator voltage constant during no load operation or station servicing, large generators need a fast-response excitation system capable of adapting the air-gap flux rapidly to load conditions. Static excitation units are particularly suited to the purpose.

Transport

With the exception of the smallest generators, the stator, front covers, rotor and all other components are shipped separately.

Testing

Material acceptance, manufacturing and the following tests are performed:

- hydraulic pressure test and leakage check on stator frame
- stator core magnetisation test
- HV test, tang delta, winding resistance and insulation resistance measurement on stator winding
- rotor overspeed to 120% of nominal value after balancing
- insulation resistance, HV test, resistance and impedance of rotor winding
- gas-tightness of lead bars and studs.

Running tests can be performed on request, including open circuit tests, steady and sudden short circuit tests, temperature and losses evaluation, wave form and harmonic content analysis.

HYDROGEN - STATOR WATER COOLED TURBOGENERATORS GENERAL CHARACTERISTICS

Generators have direct cooled stator windings through demineralized water and direct cooled rotor windings with hydrogen.
Stator core is direct cooled with hydrogen.

Frequency Hz	Speed RPM	Power factor	Rated Voltage kV	Power Range MVA
50/60	3000/3600	0,8 - 0,9	18 - 27	400 - 900

- Mounting arrangement: IM7305
- Method of cooling: IC 8 (H1) W7
  IC 9 (W7) W7 stat. winding
- Protection degree: IP 54 (IEC 60034-5)
- Excitation: static
- Hydrogen pressure: 4 - 7 bar
- Thermal insulation class: F; thermally loaded only to class B
- Terminal location: 6 below
- Installation: indoor or outdoor

HYDROGEN COOLED TURBOGENERATORS GENERAL CHARACTERISTICS

Generators have indirect cooled stator windings and direct cooled rotor windings.
Hydrogen is used as a coolant fluid.
Stator core is direct cooled with hydrogen.

Frequency Hz	Speed RPM	Power factor	Rated Voltage kV	Power Range MVA
50/60	3000/3600	0,8 - 0,9	up to 21	up to 600

- Mounting arrangement: IM1105, IM1106, IM7305
- Method of cooling: IC 8 (H1) W7
  IC 8 H1 W7 stat. winding
- Protection degree: IP 54 (IEC 60034-5)
- Excitation: static
- Hydrogen pressure: 3 - 6 bar
- Thermal insulation class: F; thermally loaded only to class B
- Terminal location: 3 above + 3 below
- Installation: indoor or outdoor

Ansaldo Energia has over 150 years experience in the electrical and mechanical engineering business.
It is a global player in the power generation sector with an installed capacity of over 176,000 MW.
Ansaldo Energia offers the full range of manufacturing, engineering, contracting and service activities, as well as a flexible approach to power projects.
Steam fossil fired, gas turbine and combined cycle, hydroelectric, geothermal and nuclear power plants, supplied turnkey, in separate lots or by components.
The Quality Systems, certified as complying with ISO 9001 by a recognised certification society, cover all aspects including, design, planning, manufacture, testing, inspection, installation and servicing.

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Reference standards

Generators are designed in compliance with IEC 60034-1, IEC 60034-3 and IEEE Standard.

Coupling

Ansaldo Energia generators can be coupled to both steam and gas turbines with or without gearing.
The standard rotor coupling is integral with the rotor shaft. Different coupling arrangements including shrunk-on and double couplings for single shaft combined-cycles can also be supplied following assessment on a case-by-case basis.

Start up and after sales services

Ansaldo Energia offers a full range of services and qualified personnel for erection and/or supervision, startup and testing. The availability of standard arrangements and in some cases package solutions ensures rapid, problem-free erection and startup.
The Ansaldo Service Organisation provides technical assistance services worldwide in the fields of maintenance, spare parts supply and preventive maintenance programs, so ensuring that customers are in the best position to achieve optimum operation.
The Ansaldo Service Organisation also provides customers with personnel training courses organised in house using specially prepared didactic materials.