



High Voltage Generators

# TM21-TG Series

2-Pole Air Cooled Turbine Generator

*Up to 80,000 kW (107,000 HP)*



TMEIC has a proud and rich history of providing the latest generator technology for a broad range of industrial markets.

Our application and design experience results in generators that are reliable and have low operating costs. We utilize the latest mechanical and electromagnetic design tools to assure our products meet customer requirements while optimizing performance and efficiency of operation.

TMEIC offers customers total support through our global service network, providing commissioning, installation and startup services.

Feature of

# T M 2 1 - T

## Flexibility

TMEIC designs generators for each customer's requirements. Each generator is customized and designed during the engineering stage.

- Compliance with global standards (IEC, IEEE)
- Unique design requirements (cooling system, excitation type, etc.)
- Performance (Efficiency, power factor, short-circuit ratio, impedance, etc.)

# G



## Reliability

TMEIC generators offer highly reliable performance.

- TMEIC's VPI (Vacuum Pressure Impregnation) insulation technique is standard and results in longer generator life
- Low noise and vibration
- Stator spring support system reduces the influence of electrical magnetic force
- Optimal rotor stiffness with cross slot reduces the specific frequency vibration
- Rotor is manufactured and tested by a high speed balancing machine

## Maintenance

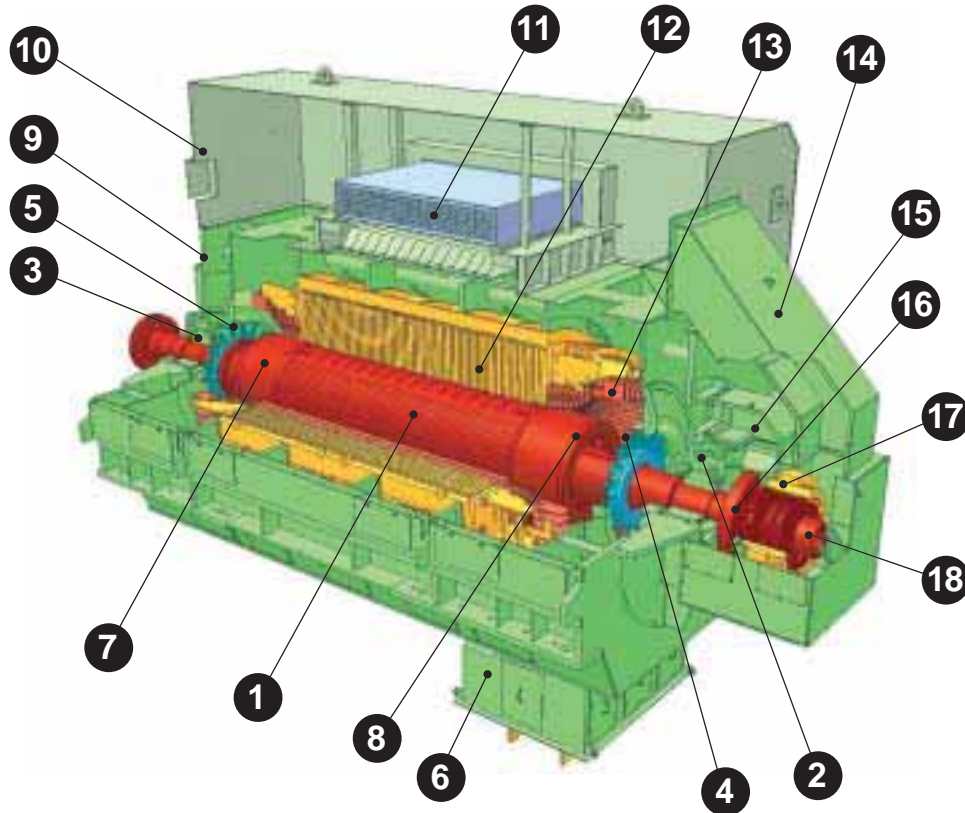
Less maintenance

- Brushless type AC-exciter system is easy to maintain and provides long continuous operation. Thyristor type with brush is also available
- Bracket type generator is transported without dismantling
- A world wide standard sleeve bearing with an air seal system eliminates oil leakage

# Internal Construction

Typical generator construction is shown below. The cooler is mounted on the top, AC-exciter with PMG is at the anti-coupling side and the frame includes a bearing bracket.

The generator is completely assembled and tested at the factory, and shipped without dismantling.



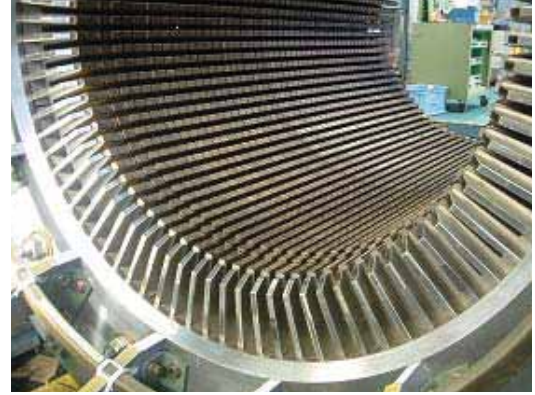
Part NO.	NAME OF PARTS	Part NO.	NAME OF PARTS
1	ROTOR SHAFT	10	AIR COOLER COVER
2	BRACKET	11	AIR COOLER
3	BEARING WITH INSULATION	12	STATOR CORE
4	FAN	13	STATOR COIL
5	FAN GUIDE	14	EXCITER INLET AIR DUCT
6	MAIN TERMINAL BOX	15	EXCITER OUTLET AIR DUCT
7	RETAINING RING	16	ROTARY RECTIFIER
8	END PLATE	17	AC.EXCITER
9	FRAME	18	PMG

- A Totally Enclosed Air-to-Water-Cooled (TEWAC) type generator is protected from dust, debris, water, etc. The standard protection of degree is IP54; IP55 is proposed for severe conditions.
- The line and neutral main terminal box is located at the bottom of the generator for mezzanine installation type turbine generator systems. The cooler is located at the top, as well as the cooling water inlet / outlet interface, so the turbine generator mechanical system will not be interrupted.
- Lubrication oil is supplied through a common turbine oil unit; the connection point is in conjunction with the coupling and anti-coupling bearing.
- An over-hang type AC-exciter with PMG is integrated with the main shaft, utilizing a common cooling air approach.

# Stator

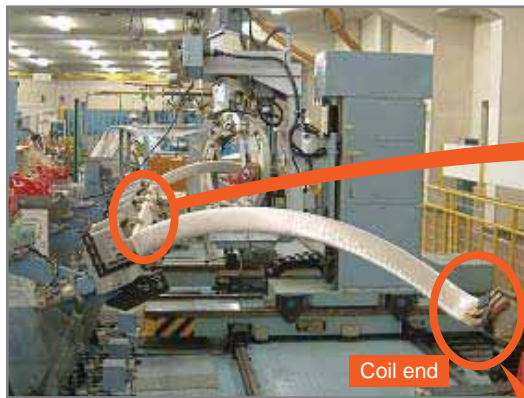
## Stator Cores

- Stator cores are high quality fan-shaped silicon steel plates, vertically laminated by a computerized robot during production.
- A high tension press machine fixes the stator cores after lamination.

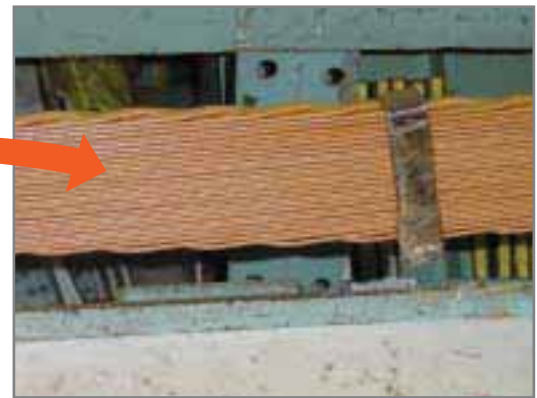


## Stator Coils

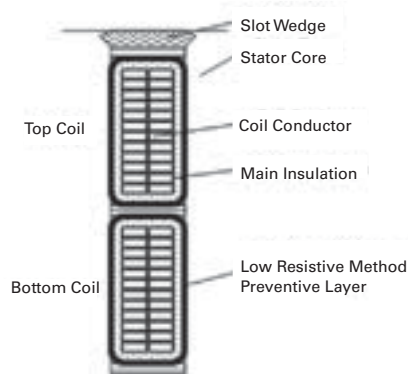
- A wrapping machine wraps each winding coil and set in the stator. The coil end is firmly attached to alleviate harmful vibration.
- Conductors are transposed at the ends to minimize eddy-current losses.
- For one-turn coils, Roebel transportation and External transportation are employed to minimize effectiveness. ?



Coil end



Roebel transportation



Stator Coil in Slot



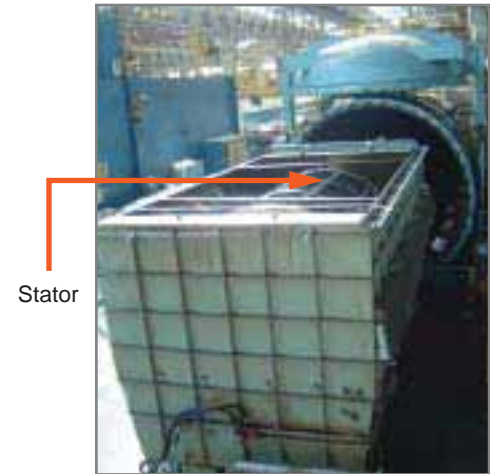
Coil End  
External transportation



# Stator

## VPI Treatment

The entire stator and coil is insulated using a vacuum pressurized impregnation (VPI) technique. To increase reliability, all of the iron core parts, including the bound parts of the coils, are impregnated with resin.



Stator

## Frame

After the VPI process has been completed, the stator is fixed to the frame using a spring support system, which reduces the deformation vibration from the stator to the frame.

The stator core is supported by a robust rectangular frame, with bearings attached to the frame. This standardized design achieves vibration-free operation. The temperature and vibration instrumentation for remote sensing and the junction boxes (auxiliary boxes) is provided at the side of the generator frame. Flexible arrangement of these boxes makes external cable connection easy.



## Main Terminal

Line and neutral main terminals are located at the bottom of the generator frame. Six terminals are available with star connection winding. The terminals are enclosed in the main terminal box for NSPB (Non Segregated Bus Duct) or cable. Several configurations for mounting the CTs to the control panel accommodate various designs.



Terminal

# Rotor

## Machining Rotor Shaft

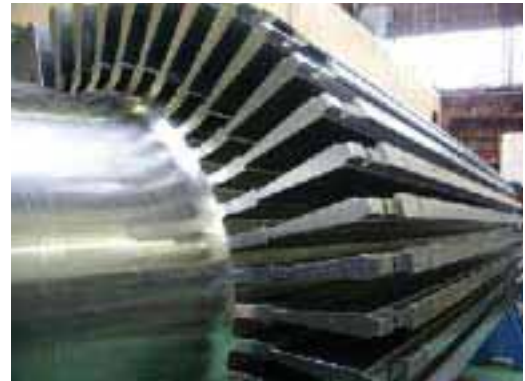
Strict quality guidelines for a special steel alloy are met by our suppliers. The alloy quality is ensured through ultrasonic law analysis.

Standard machining includes cross slots at the Y-axis. The rotor balance test is carried out after machining.



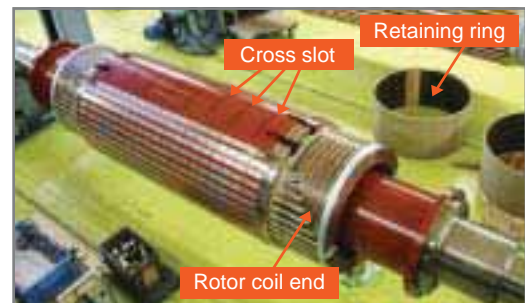
## Rotor Shaft

A 2-pole turbine generator's performance is reliant upon the quality of the rotor's material and the manufacturing process. Special alloy steel material is selected for the rotor shaft so it can withstand large centrifugal force under 3,000 min-1 or 3,600 min-1 operation. The material inspection with ultrasonic flaw detection and rotor balance test are carried out after machining.



## Completed Rotor Shaft

The rotor coil end extends to the anti-coupling side, and is shrinkage-fitted to the retaining ring. The ring is made of nonmagnetic 18 Mn / 18 Cr steel for large capacity machines. A high speed balancing test of the rotor is carried out before final assembly. Cross slots engraved at Y-axis equalize the stiffness at X-axis and Y-axis, resulting in a well-balanced machine.



# Rotor

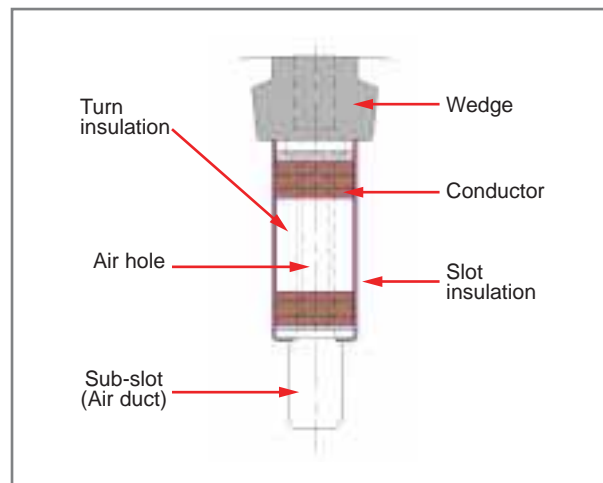
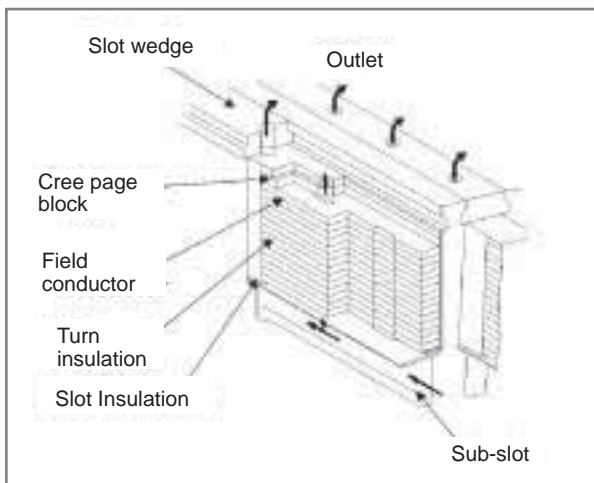
## Rotor Coils

Rotor conductors are flat, annealed copper plate material and wrapped by insulation tape (mica) between layers and inside the slot. Nonmagnetic wedges driven into the slot hold the coils in place.



## Method of Cooling

The rotor coil is cooled by air passing through ducts and holes cut under rotor slots and coils.



## Coupling End

The turbine coupling end is a forged integral type. During the manufacturing stage, the template turbine manufacturer supplies are used to comply with the actual dimension of coupling.





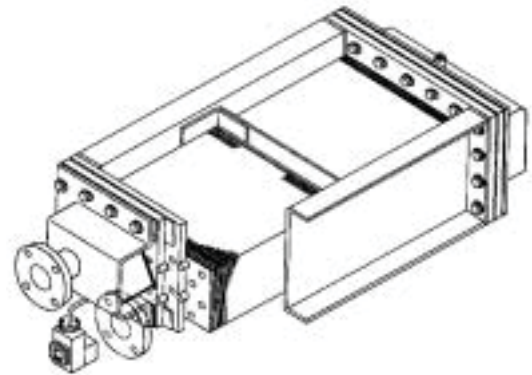
# Cooler and Lubrication

## Cooler Unit & Ventilation System

The cooler is mounted on top of the generator before transport. A protective sheet protects the generator from water flowing from the cooler.

The standard cooler tube material is 90-10 cupronickel, 2x67% capacity coolers meet the IEC standard. Various options are available to meet project requirements and water quality, etc.

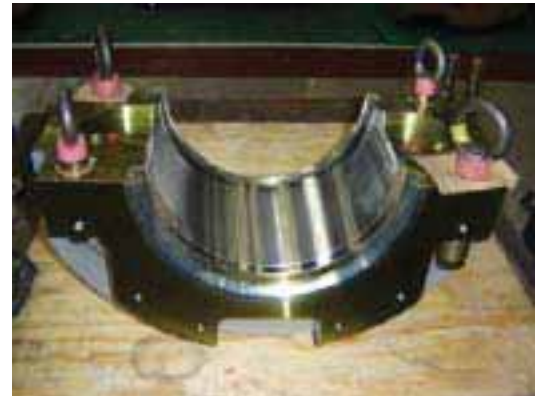
External cooling air circulates in the generator body. Heated air is cooled as it circulates through the cooler.



## Bearing

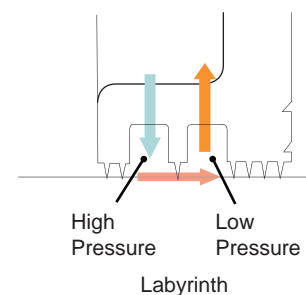
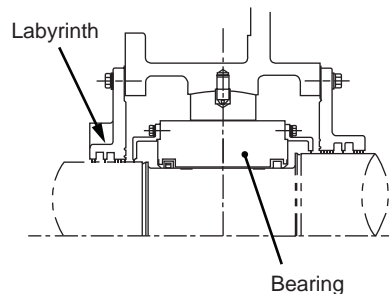
A sleeve bearing with forced oil lubrication reduces maintenance. A positive pressure air seal structure prevents oil leakage from entering the generator.

The bearing is electrically isolated between the rotor shaft and frame to prevent shaft current from being circulated.



## Lubrication System

The turbine oil unit supplies forced lubrication oil to the sleeve bearing. Properly sized inlet and outlet pipes smooth the oil flow and prevent vapor phenomena. An air seal labyrinth prevents oil leakage. The arrangement of flange location, piping material and instrumentation of the lubrication system are determined during the engineering phase.



Air seal structure

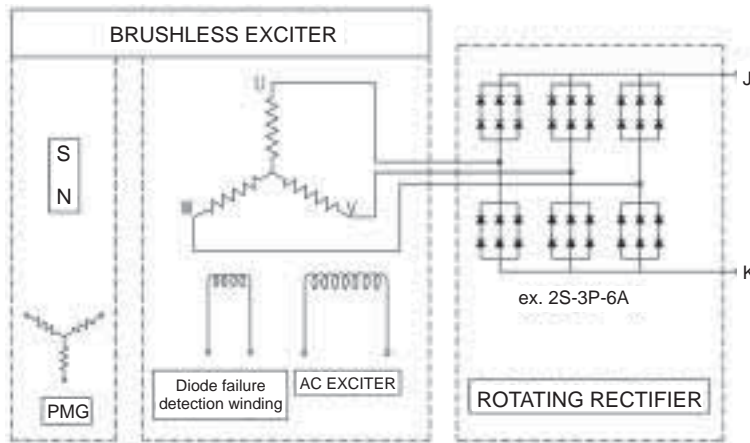
# Excitation System

A brushless type excitation system with permanent magnetic generator (PMG) is standard, designed for low, easy maintenance and continuous operation. The system consists of an AC-exciter, a rotary rectifier and a PMG.

The AC-exciter is a 3-phase AC generator of the revolving armature type. The rotating rectifier circuit is mounted firmly on the shaft's anti-coupling side. Excitation power is supplied from the PMG during generator rotation, eliminating the need for initial excitation. Field current supplied by the PMG maintains a level current when a short circuit occurs. A rectifier diode has enough margin to satisfy severe operation, no discharge resistor is required.

## Rectifier

Rotating rectifier is mounted on the shaft, and consists of three parallel diodes with two serials for 6 arms (2S-3P-6A). The redundant diode system achieves high reliability and allows continuous operation of the generator.



## Excitor and PMG

Brushless exciter with PMG is over-hanged on the generator shaft. So, additional bearing is not necessary. Collector ring is not equipped and there is no carbon brush and no carbon dust, no daily inspection is required.

## Failure Detector

Both diode failure and field earth fault are detectable.

## Excitor Option

The exciter overhangs the bracket in the standard configuration; a third bearing is not required. A separate large capacity AC exciter is provided when special performance is required. A static type collector ring is available as an option to meet project requirements.



PMG AC Exciter

# Other Features

## Enclosure

The natural ventilation type outdoor enclosure can be provided for sound proof and/or severe environmental circumstance, equipped with inner luminescence and entrance door. The enclosure is divided into adequate size plates for shipping and can be easily assembled on site. Enclosure dimensions are designed to accommodate the turbine cover as well as installation limitations.



## Instrumentation

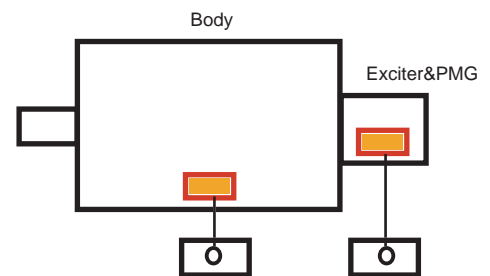
Various type instrumentation is equipped on the generator for remote sensing and local indication, such as, RTD (Resistance Temperature Detector) for stator winding and inner air temperature detection, vibration probe for shaft and bearing housing running condition monitoring, leakage water detector, etc.

The orifice at oil inlet flange is also provided after calibration during actual oil flow test at our factory. The detail application is fixed during the engineering stage to comply with the customer's requirements.

Standard Instructions		
Designation	Qty.	Type
Winding temperature	6	RTD
Inner air temperature (cold/hot)	3 or 4	RTD
Bearing temperature	2	RTD
On-shaft vibration	2	-
Water leakage detector	1	-
Orifice	2	-

## Space Heater

Separate space heaters for the generator body and AC-exciter for anti-condensation are standard. The suitable rating is designed for site ambient condition and the heater operation reconciled with stopping status.



## Sole Plate and Fixing Bolt

Sole plate, fixing bolt, shim, etc. are standard and can be delivered prior to shipping the generator.



# Test & Inspection

## Generator Testing

Generator testing is performed in accordance with IEC60034 standard unless otherwise specified. The generator will be driven by a suitable motor for the test.

Test Item	First Unit (No. 1)		Duplicate Unit (No. 2)	
	Factory Test	Witness Test	Factory Test	Witness Test
A. Electrical measurement test (with AC excitor)				
1) Measurement of coil resistance	○	△	○	△
2) Measurement of insulation resistance	○	○	○	△
3) Dielectric test	○	△	○	△
4) Open-circuit characteristic test, voltage balance, and phase sequence check	○	○	×	×
5) Three phase short circuit characteristic test and current balance check	○	△	×	×
6) Measurement of segregated losses	○	△		
7) Efficiency calculation	○	△	×	×
8) Equivalent heat run test	○	△	×	×
9) THF measurement	○	△	×	×
B. Mechanical inspection and test (with AC excitor)				
1) Outline and layout check	○	○	○	△
2) Measurement of vibration	○	○	○	△
3) Overspeed test	○	△	○	△

○: marked item will be tested

△: marked item will be tested, report will be submitted

×: marked item will not be tested

## Rotor Shaft Balance Test

A high speed dynamic balance test is carried out after completion of rotor assembly at our factory. Along with measuring the minimum the vibration, rotor balance is adjusted by adding a small weight under different speeds, up to rated speed, and at 120% of rated speed.



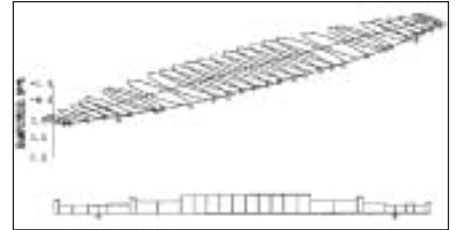
# Research and Development

## Research Introduction

Ongoing research seeks to improve the 2-pole generator. Design encompass a wide range of applied knowledge including electromagnetic, mechanical, material, and insulation techniques.

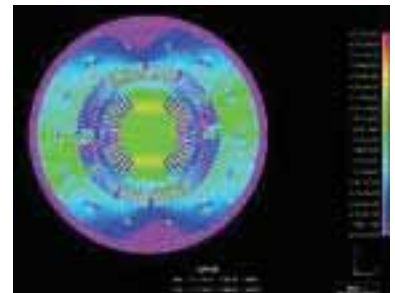
## Rotor Characteristics Research

To achieve the desired characteristics, critical speed, Qfactor, vibration mode and bearing stability are analyzed for each generator, measuring balance weight effect and vector during routine testing. The 2-pole generator is long and thin, and can rotate at high speed.



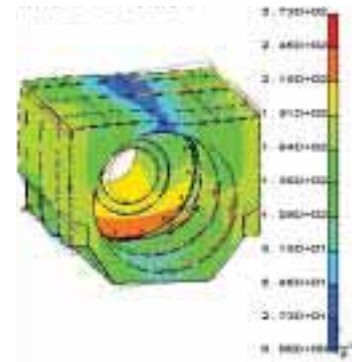
## Magnetic Flux Research

Magnetic flux analysis leads to the design of a high efficiency machine. Efficiency is increased by reducing the leakage of magnetic flux. Additionally, local heating caused by excessive magnetic flux density is eliminated.



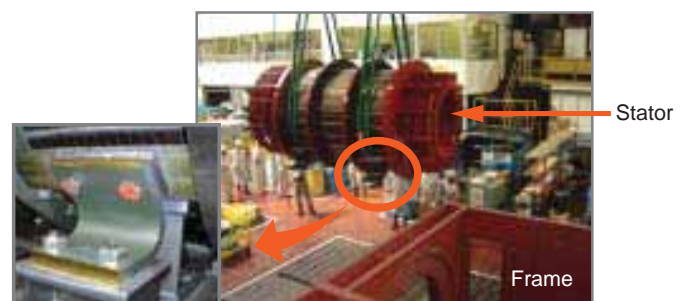
## Frame Natural Frequency Research

The frame is subjected to excitation force from the stator core. Frame vibration grows when the natural value harmonizes excitation frequency, introducing various problems. Frequency analysis evaluates the electromagnetic field strength of frame natural frequencies.



## Developing Improved Design

Improvements from research and design results include a better spring support system for electromagnetic vibration. The new design eliminates vibration transmission between the stator core and the frame. Additionally, frame construction is simpler.



Spring support system

# Specification

Item	Standard Specifications	Options
<b>Ratings</b>		
Rated output	5,000 ~ 100,000 kVA (approx.)	
Rated voltages	11 kV, 13.8 kV	According to customer's specifications
Frequency	50 Hz or 60 Hz	
Poles	2	
Rated speed	3,000 min <sup>-1</sup> or 3,600 min <sup>-1</sup>	
Rated power factor	85% lagging	According to customer's specifications
Enclosure type	Totally enclosed, water to air cooled (TEWAC)	
Protection	IP54	According to customer's specifications
Cooling method	IC8A1W7	According to customer's specifications
Applicable standard	IEC60034	According to customer's specifications
<b>Site conditions</b>		
Location	Indoor	Outdoor
Ambient temperature	Max +40° C min, -5° C	According to customer's specifications
Altitude	Less than 1,000 m	According to customer's specifications
Humidity	Less than 95%	According to customer's specifications
Voltage variation	Less than ±5%	According to customer's specifications
Frequency variation	Less than ± 2%	According to customer's specifications
Rotor configuration	Cylindrical Rotor	
Insulation rating	F-Class Insulation	
Temperature rise	F-Class temperature rise	B-Class temperature rise
Excitation system	Brushless excitation (with PMG)	According to customer's specifications
Direction of rotation	According to customer's specifications	
<b>Shaft construction</b>		
Shaft extension	Single shaft	According to customer's specifications
Shaft end geometry	Solid	According to customer's specifications
<b>Air cooler</b>		
Location	Top mount	According to customer's specifications
Water inlet temperature	32° C	According to customer's specifications
Supply pressure	0.5 MPa (allowable design value)	According to customer's specifications
Water type	Fresh water	According to customer's specifications
Cooling tube	Single tube	According to customer's specifications
Tube material	90-10 Cu-Ni	According to customer's specifications
Direction of piping flange	Left side (viewed from exciter side)	Right side (viewed from exciter side)
<b>Bearings</b>		
Type	Sleeve bearings (forced lubrication)	
Oil temperature	45° C	According to customer's specifications
Oil pressure	approx. 0.1 MPa	
Lubricating oil	ISO VG32	According to customer's specifications
Direction of piping flange	Left side (viewed from exciter side)	Right side (viewed from exciter side)
<b>Main terminal</b>		
Number of terminals	6 (star connection)	According to customer's specifications
Terminal box position	Bottom	According to customer's specifications

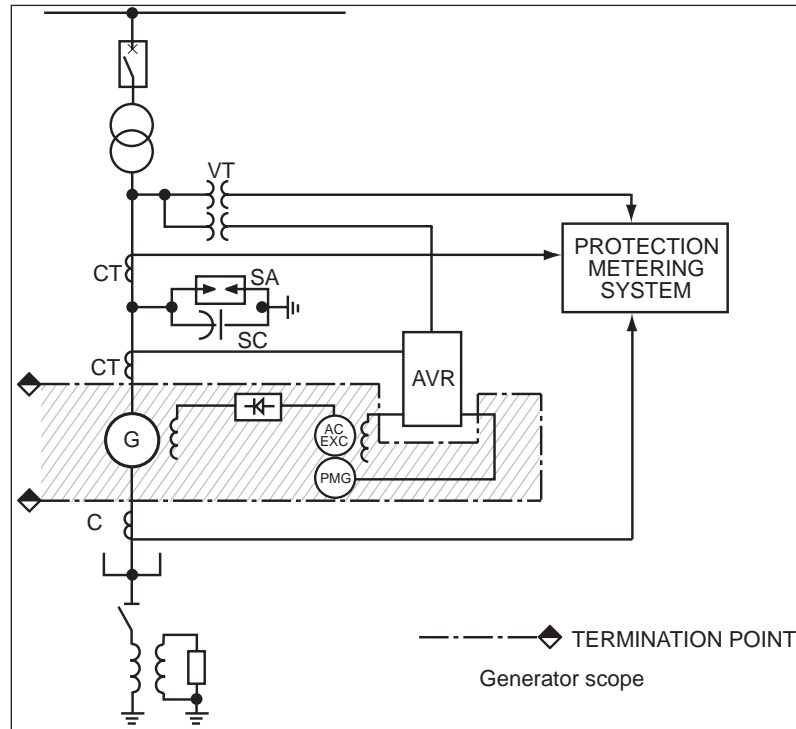
# Specification

Item	Standard Specifications	Options
<b>Paint</b>		
Color	Munsell 2.5 PB6/2	According to customer's specifications
Thickness	50µ m or above	According to customer's specifications
<b>Accessories</b>		
	1 set - sole plate	
	1 set - fixing bolts	
	6 pcs - stator winding temperature detector RTD	
	2 pcs - bearing temperature detector RTD	2 pcs - dial type bearing temperature indicators
	2 pcs - inlet air temperature detector RTD	
	1 pc - outlet air temperature detector RTD	
	1 set - space heater	
	1 set - auxiliary terminal box for instrumentation	
	1 pc - air cooler water leakage detector	
	1 set - orifice for lubrication oil inlet	
	1 set - earth terminal	
	1 set - special tool	
	1 set - vibration probe fixing work at factory	
		Probes to be supplied by turbine manufacturer
		1 set - oil flow sign
		1 set - copper belt/carbon brush from shaft earthing

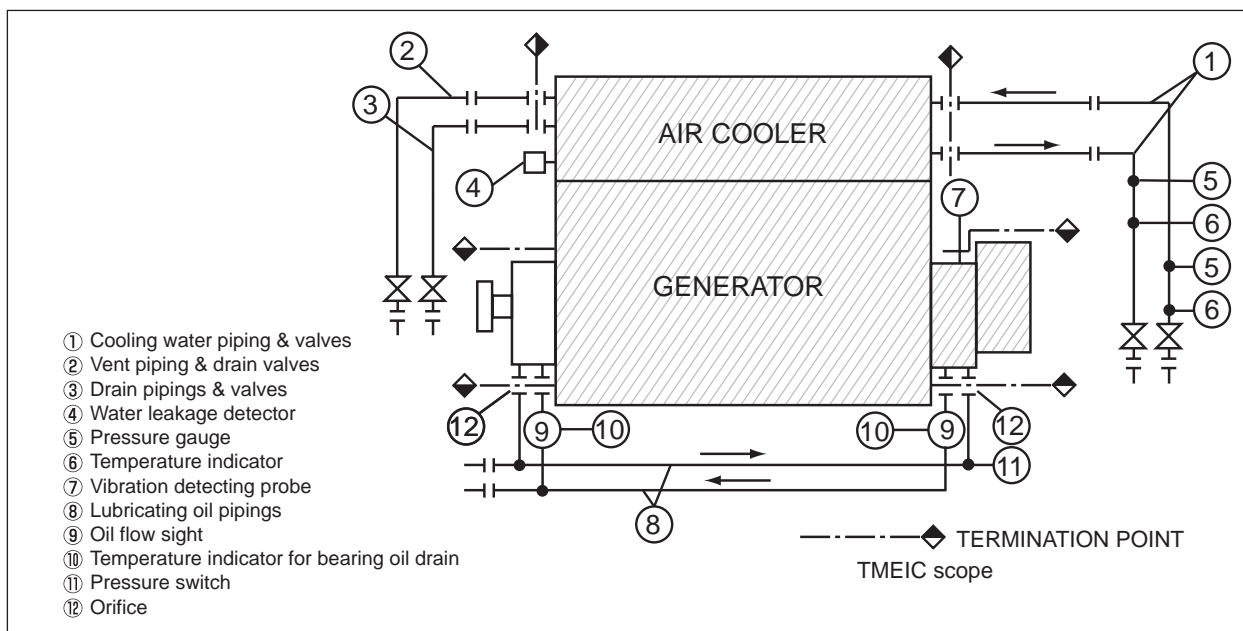
# Termination Point

The single line diagram and piping & instrument diagram show the typical termination point of the generator system with excitation and purchaser's scope.

## Electrical System



## Lubrication System



# TMEiC

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