4-Pole Air-Cooled Turbine Generator
**What is TMEIC?**

TMEIC (Toshiba Mitsubishi-Electric Industrial systems Corporation) has a proud and rich history of providing the latest generator technology for a broad range of industrial market. Many application and design experience make the solutions that have high reliability and lowest expense of customer. We utilize the latest mechanical and electro-magnetic design tools to assure our product meets customer requirements while achieving performance, efficiency of operation.

Not only for providing the equipment, TMEIC also supports the customer’s engineering works and site commissioning to complete the generator system.

**Maintenance**

Easy and less maintenance is important for operation.
- Brushless type AC-exciter system, our standard excitation system, realizes the easy maintenance and long continuous operation.
- The world wide standard sleeve bearing is used and no oil leakage occurs at bearing by floating labyrinth seal system.

**Reliability**

TMEIC offers the best and highest reliable performance.
- High insulation technique with global VPI (Vacuum Pressure Impregnation) is TMEIC standard insulation procedure by large VPI facility, which provides many benefits to the customer and achieves a longer life.
- Robust rotor construction.
- The rotor is of salient solid pole construction. The rotor shaft is integrated with the pole bodies, which makes the shaft more rigid, increasing reliability up to over speed.

**Flexibility**

TMEIC provides the various kind of generator for customer’s requirement. Each generator is customized and designed during the engineering stage.
- Compliance to global standards (IEC, IEEE)
- Project requirement (Cooling system, excitation type)
- Performance (Efficiency, Power factor, Short-circuit ratio, Impedance, etc.)

**Feature of 4-Pole Turbine Generator**

Toshiba and Mitsubishi Electric lead the large generator business field and TMEIC is assigned to the market of large capacity 4-pole generator for global requirement.

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- Brushless type AC-exciter system, our standard excitation system, realizes the easy maintenance and long continuous operation.
- Bracket type generator is available to be transported and installed without dismantling. The world wide standard sleeve bearing is used and no oil leakage occurs at bearing by floating labyrinth seal system.
INTERNAL CONSTRUCTION

A typical construction of generator is shown below. The cooler is mounted on the top, AC-excitier with PMG (Permanent Magnetic Generator) is at the anti-coupling side and the frame has bearing bracket. The generator is assembled completely and tested at our factory and shipped without dismantling. This feature enables a compact size and small foot print. The minimum erection work is required.

STATOR

Stator Cores

Stator cores are high quality silicon steel plates and are laminated vertically by computerized robot automatically. After lamination, they are fixed with high tension by press machine for stator.

Stator Coil

Each winding coil is wrapped with insulation tape by wrapping machine and they are set in the stator. Coil end is stiffened so firmly by experienced workers that no vibration harmful occurs.

Part NO. | NAME OF PARTS
--- | ---
1 | ROTOR SHAFT
2 | BRACKET
3 | BEARING WITH INSULATION
4 | FAN
5 | FAN GUIDE
6 | MAIN TERMINAL BOX
7 | ROTOR COIL
8 | POLE HEAD
9 | ROTOR COIL BRACKET
10 | FRAME
11 | AIR COOLER COVER
12 | AIR COOLER
13 | STATOR CORE
14 | STATOR COIL
15 | EXCITER SUPPORT
16 | ROTARY RECTIFIER
17 | AC. EXCITER
18 | PMG

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Totally Enclosed Air-to-Water cooled type generator protects environmental affect, such as, dust, debris, water splash, etc. The standard protection of degree is IP44 for indoor, IP54 for outdoor, and IP55 is proposed for severe condition. The line and neutral main terminal box is located at the side of generator for easy installation. The cooler is located at the top and cooling water inlet/outlet interface location is upper, not to interrupt the turbine and generator mechanical system. The lubrication oil is supplied by common oil unit of turbine and the connection point is conjunction with coupling and anti-coupling side bearing. Over-hang type AC-excitier with PMG is integrated with main shaft and the common cooling air is used.
The rotor is constructed of the pole body, pole heads and field coils. The pole body is machined from a single steel forging and is of salient pole construction. To cope with vibration and overspeed, the rotor shaft, which is forged integrally with the pole body, is designed to withstand the primary critical speed being increased by 20% or more over the rated speed. This means that starting and stopping can be performed without passing the primary critical speed, resulting in greater resistance to vibration.

The rotor coil is fabricated from rectangular copper strips, with fin effects for optimum cooling. Insulation is provided between layers, and field coils are formed under pressure and heat.

After the pole body has been fitted with field coils, the pole head are tightly bolted. All bolts, subjected to nondestructive inspection, are tightened under strict fastening control to ensure high reliability.
COOLER AND LUBRICATION

Cooler unit & Ventilation system

Cooler is mounted on the top of generator to transport and install with generator without additional site works. Even though water leakage occurs in the cooler, the water goes down on the protection sheet between cooler and generator frame and it is detected water leakage detector. The standard cooler tube material is deoxidized copper. Various options are proposed for project requirement and water quality, etc.

Cooling air is isolated from the external and circulates in the generator body. The heated air goes through the cooler and becomes cold.

Bearing and Lubrication system

Sleeve bearing with forced oil lubrication makes the simple and excellent maintenance. Air seal structure prevents oil leakage, since it keeps the internal air positive pressure that no oil enters into the generator. The bearing is electrically isolated between rotor shaft and frame not to circulate the shaft current at anti-coupling side.

Forced lubrication oil is supplied from turbine oil unit for sleeve bearing. The enough size inlet and outlet pipes make the smooth oil flow and prevent the vapor phenomena. Floating labyrinth seal of bearing also prevents oil leakage.

EXCITATION SYSTEM

Excitation system: Brushless type excitation with PMG (Permanent Magnetic Generator) is our standard and recommended for easy and less maintenance with continuous operation. The system consists of an AC-exciters, a rotary rectifier and a PMG. AC-exciters is a 3-phase AC generator of the revolving armature type and the rotating rectifier has a rectifier circuit mounted on shaft firmly at anti-coupling side. No initial excitation is required. Because excitation power is supplied from PMG during generator rotates. Short circuit current also keeps its value by field current supplied from PMG when short circuit occurs. Rectifier diode has enough margined to satisfy the severe operation.

Rectifier

Rotating rectifier is mounted on the shaft, and consists of high reliability diodes for 6 arms (1S-1P-6A). Discharge resistor protect the diodes from abnormal induced voltage.

Exciter 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.
When cooling water is not available, we can apply totally enclosed air to air (TEAAC) type enclosure.

**Accessories**

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, 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 customer’s requirement.

The separate space heaters for generator body are provided as standard for anti-condensation. The suitable rating is designed for site ambient condition and the heater operation is coincided with stopping status. Sole plate, fixing bolt, shim, etc. are standard scope. They can be delivered separately prior to the generator shipping schedule.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Quantity</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winding temperature</td>
<td>6</td>
<td>RTD</td>
</tr>
<tr>
<td>Inner air temperature(cold/hot)</td>
<td>3</td>
<td>RTD</td>
</tr>
<tr>
<td>Bearing temperature</td>
<td>2</td>
<td>RTD</td>
</tr>
<tr>
<td>Water leakage detector</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Orifice</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Space heater</td>
<td>1 set</td>
<td></td>
</tr>
<tr>
<td>Scale plate</td>
<td>1 set</td>
<td></td>
</tr>
<tr>
<td>Anchor bolts</td>
<td>1 set</td>
<td></td>
</tr>
</tbody>
</table>

To minimize the vibration at operate condition, the rotor balancing is adjusted by adding the weight on each correction plane. For up to 30,000kVA, two plane dynamic balancing test is carried out after completion of the rotor assembly. Over 30,000kVA, running balance test is carried out after final assembly.

## TESTS OF GENERATOR

The tests of generator are performed in accordance with IEC60034 standard unless otherwise specified. The generator will be driven by a suitable driving motor during running test.

### TEST & INSPECTION

<table>
<thead>
<tr>
<th>Test Item</th>
<th>First Unit (No.1)</th>
<th>Duplicate Unit (No.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Electrical measurement and test for generator (with AC exciter)</td>
<td>Factory Test</td>
<td>Witness Test</td>
</tr>
<tr>
<td>1) Measurement of coil resistance</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2) Measurement of insulation resistance</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3) Dielectric test</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4) Open-circuit characteristic test and voltage balance and phase sequence check</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5) Three phase short circuit characteristic test and current balance check</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6) Measurement of segregated losses</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7) Efficiency calculation</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8) Equivalent heat run test</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>B. Mechanical inspection and test for generator (with AC Exciter)</td>
<td>Factory Test</td>
<td>Witness Test</td>
</tr>
<tr>
<td>1) Outline and layout check</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2) Measurement of vibration</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3) Overspeed test</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

- ☐ : marked item will be done.
- ☐ : marked item will not be done. Test report will be submitted.
- ☐ : marked item will not be done.
We continue developing in pursuit of a better 4-pole generator. It needs design and manufacture technique to judge the application for creation plan. The design technique involves the following wide range of special knowledge which are electromagnetic, mechanical, material and insulation. This chapter introduces an example of the research.

**Research 1 (Rotor characteristic)**

4-pole generator rotor is long and thin, additionally, rotated high speed, so we should get the characteristic. Critical speed, Q-factor, vibration mode and stability of bearing are analyzed for each generator, measuring balance weight effect and vector at routine test process.

**Research 2 (Magnetic flux)**

Magnetic flux analysis is effective for design of high efficiency machine. It leads to high promotion of efficiency to reduce leakage magnetic flux. In addition, we can avoid a local heating by excessive magnetic flux density.

**Research 3 (Frame eigen frequency)**

Frame is joined to stator core, so it is subjected to excitation force by stator core. If frame eigen value harmonize excitation frequency, frame vibration grows, and it occur various problems. We get a frame eigen frequency with analysis and confirm vibration with measurement for real machine.
The single line diagram and piping & instrument diagram show the typical termination point of our generator system with excitation and purchaser's scope.

**Electrical system**

**Lubrication and Cooling water system**