Mitsubishi Electrical manufactures brushless exciters for all types of turbine generator, including air-cooling, hydrogen-cooled, and inner-cooled type.

The total number of Mitsubishi brushless exciters produced has climbed to more than 300 units since the first one was produced in 1965.

The large area a 5,500kW, 1,800rpm exciter for nuclear-power-plant generators, and a 3,700kW, 3,000rpm exciter for fossil-fuel power-plant generators.
**PRINCIPLE**

Fig. 1 shows the principle of Mitsubishi brushless exciter systems. The output of an AC exciter is led to a rotating rectifier equipped with diodes, where it is converted to DC, and supplied to the rotting field of a turbine generator. The armature of the AC exciter, the rotating rectifier, and the turbine-generator field are mounted on the same shaft, eliminating the need to lead out the DC output to a stationary part, thus eliminating the necessity of such sliding parts as a commutator, slip rings, and brushes.

The field of the AC exciter is excited by a permanent-magnet generator (PMG) functioning as a pilot exciter and controlled by a thyristor-type AVR (automatic voltage regulator).

**FEATURES**

- **Manpower Saving**
  Since there are no brushes, there is no necessity for inspection of generator slip rings or brush replacement during operation, thus manpower saving can be achieved.

- ** Stable, Continuous Operation**
  This is made possible during an extended service life because the power supply is ensured by rotation of generator, and by elimination of troubles associated with brushes.

- **Superior Economy**
  Thanks to the exciter’s simplified construction, system layout is easy. Contribution to the system’s high-economy advantages are low installation requirement costs and direct drive of the main shaft resulting in reduced power consumption by auxiliary equipment.

**STANDARD SPECIFICATIONS**

- **Rated Current**
  The current rating of Mitsubishi brushless exciters is determined to be larger than the field current necessary for operating the generator at the rated kVA, rated power factor, and rated voltage.

- **Temperature-Rise Limit**
  The temperature-rise limit at various ports of Mitsubishi brushless AC exciters is as follows:
  - Normal ambient temperature: 50 deg C
  - Armature windings: 60 deg C rise
  - Field windings: 60 deg C rise
  (Thermometer method)

- **Insulation Class**
  Class B or Class F insulation is applied to both the armature winding and field winding.

- **Exciting-System Response Characteristics**
  - Exciter-Voltage response ratio: 1.0 or higher
  - Exciter ceiling voltage: 1.4 times or more than voltage of the generator under rated load

- **Tests**
  When an exciter is completed in the factory, it is subjected to the following routine test. Type tests are conducted only on exciters of a new design.
  1. Routine Tests
     a) 15% overspeed strength (for 2min)
     b) Vibration measurement and mechanical balance.
     c) Resistance measurement of armature and field windings.
     d) Insulation-resistance measurement.
     e) Dielectric test: An AC voltage of 10 Ex (1,500V, min., 5,000V, max.) is applied for 1min at commercial frequency to the armature winding.
     f) Visual and dimensional inspection.
  2. Type Tests
     a) No-load saturation characteristic measurement.
     b) Measurement of losses.
     c) Equivalent temperature-rise test.
OVERALL

Fig. 2 is a sectional drawing of a typical brushless exciter are mounted on the same shaft, and the shaft end on the rotating rectifier side is connected to the rotor shaft of the turbine generator through a coupling. The other end is supported by the exciter bearing. A lead wire from the rotating rectifier to the turbine generator is provided on the shaft. The PMG is overhung on the shaft end on the AC exciter side.

Fig. 3 shows the rotor construction. The brushless exciter is assembled on a bed and is a totally enclosed, self-ventilating system insulated against outside air by a housing. An air cooler is provided inside the housing and self-ventilation is effected by the fanning action of the AC exciter and the rotating rectifier. The housing is provided inspection during operation or shutdown.
THE AC EXCITER

The AC exciter is an ordinary synchronous generator except that it features a rotating armature, many poles ensuring a rapid response, and high frequency.

・ The Stator
Nomex is used for the ground insulation of the field coil, which is also vacuum-impregnated with epoxy resin. The external frame enclosing the magnetic field is mounted on the upper base and can be separated into two sections. This structure allows easy installation or removal of the rotor by simply removing the upper section of the frame.

・ The Rotor
The armature winding uses a 3-phase Y-connection, and Nomex is used for the ground insulation, followed by epoxy-resin vacuum impregnation. The armature core consists of a lamination of circular punching of electrical steel sheets. It is shrink-fitted over the rotor shaft, and help firmly with armature clamps from both sides. The coil ends are rigidly help with glass bonds from the armature clamps to resist a large centrifugal force during rotation.

Fig. 3 The rotor construction
THE ROTATING RECTIFIER
This consists mainly of a rectifier wheel plus diodes, fuses, and heat sinks, all of which are attached to the inner surface of the rectifier wheel. The composition of the rotating rectifier is expressed as, for example, 1S-5P-6A, in which:

- 1S: The number of diodes connected in series
- 5P: The number of diodes connected in parallel
- 6A: The number of arms (6 arms are supplied for a 3-phase full-wave bridge)

In this example, the total number of diodes is

\[ 1 \times 5 \times 6 = 30 \]

The rectifier wheel is a rigid ring for supporting the components under high-speed rotation. The diodes are fixed to the heat sinks through insulators to the inner surface or the rectifier wheel (Fig. 4). The fuses have a mechanically sturdy construction. When a fuse has opened, an indicator springs out by centrifugal force, making it easy to notice (Fig. 6).

THE ELECTRICAL CIRCUIT
For protecting the diodes against overcurrents, the fuses are provided in series. In the event that a diode short-circuits, the current the failed circuit is cut off by opening of the fuse in series. The diodes used are selected after rigorous quality control, including a rotary test. To ensure continuous operation in the unlikely event that diode failure occurs, a backup diode circuit is provided on every arm (each phase, each pole). Using diodes with a resisting capacity greater that the reverse voltage generated in the circuit if generator failure occurs has enabled simplification of the components without use of an R-C circuit, etc., and high reliability is ensured (Fig 7).

OTHER COMPONENTS

- **The Pilot Exciter**
  This PMG functions both as the exciting power supply for the AC exciter and the power supply for the AVR. It comprises a rotating magnet and a stationary armature, and ensures mechanical reliability more than high enough to withstand the compressive force acting on the magnet when it is subjected to the centrifugal force of high-speed rotation.

- **The Air Cooler**
  The heat of the circulating air is transmitted through the finned pipes of the cooler to the cooling water flowing through the pipes. The cooling pipes are made of seamless brass tubes specially made for condenser use. Both ends of the cooling pipes are provided with expansible supports for the tube plates.
**The Bed**
This is comprised of an upper section and a lower section to facilitate extraction and insertion of the turbine-generator rotor. A very rigid foundation is prepared around the bearing pedestal to increase stability against vibration owing to rotation of the shaft. That is, the upper section is bolted directly to the foundation, and free-flowing nonshrinkable grout is used to ensure firm adhesion between the base and the foundation.

**The Coupling**
It is necessary that the turbine generator and the brushless exciter be a single block that functions not only as a mechanical coupling but also as an electrical connection. Electrically, the connection lead are led through a coupling slot; mechanically, torque transmission is performed through reamer bolts.

**THE SHAFT SYSTEM**
This system is satisfactorily stabilized by direct connection of the exciter shaft and the turbine-generator shaft system. It features reliable vibration characteristics in bending and torsion, thanks to high-level analysis for the design and balance.

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**INSPECTIONS AND MAINTENANCE**

The items require inspection in the brushless exciter are the cooling-air temperature (the temperature-measuring element, etc.), The fuses can be checked easily. Each fuse is equipped with an opened-fuse indicator, which is held in a groove near the upper terminal during normal operation. When a fuse opens, the indicator springs out by centrifugal force. Even during operation, an opened-fuse can be easily detected by shining a stroboscopic light through a window in the exciter housing. To ensure stable continuous operation, a sufficient margin above the required number of diodes and parallel circuits is provided. Even if a diode fails and is disconnected from the circuit, replacement can be postponed until the next shutdown while continuing operation. As the brushless exciter receives all its operating energy from the turbine-generator shaft, it is not affected by a fault in the power-transmission system. In addition, emergency shutdowns due to malfunctioning of a commutator, slip rings, or brushes have been eliminated.

The brushless exciters are designed with ample consideration for the continuity of safe operation even under such turbine-generator transient conditions as impression of the ceiling voltage and/or asynchronous operation.