

## Mitsubishi Electric Generator Robotic Inspections “GenSPIDER®”

Generator Smart & Precise Inspection Accomplished  
by Generator Dedicated Expert Robot

# GenSPIDER®



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## 1. Introduction



Power plant availability is a key focus in the industry worldwide and continuous generator operation is more likely when a comprehensive maintenance program is implemented by the owner. However, Mitsubishi Electric recognizes the customer needs to maintain a high level of availability while minimizing maintenance costs. Therefore, the **GenSPIDER®** was developed in order to offer an alternative to frequent, costly major generator inspections while still providing intelligence as to the condition of the generator. Conventional generator inspections are costly and require a long outage duration, in part because the rotor must be removed. Electric power producers have been looking to shorten these inspections as well as improve inspection accuracy to extend the availability of their generators. Mitsubishi Electric Corporation developed a dedicated robot capable of inspecting a turbine generator by passing through the narrow gap between the rotor and stator (air gap), eliminating the need to remove the rotor. Hence, more thorough inspections can be completed within short duration outage. Further, thanks to its high accuracy, interior inspections can be carried out less frequently and help operators avoid stocking parts they do not yet actually need. As a result, **Mitsubishi Electric's new robot will help reduce total inspection costs and time**, improving both the reliability and availability of turbine generators.

Mitsubishi Electric's new robot, **GenSPIDER® (Generator Smart & Precise Inspection Accomplished by generator Dedicated Expert Robot)** crawls along the stator core and performs a visual inspection utilizing a built in high definition camera. Stator wedge tapping and EL-CID (Electromagnetic Core Imperfection Detection) tests are also options that can be performed by the robot. **GenSPIDER® can be applied to a wide capacity range of Mitsubishi Electric and Non-Mitsubishi Electric generators**. Robotic inspection will lead to reliable maintenance planning and the minimizing of forced outage risk.

## 2. GenSPIDER® Features

GenSPIDER® was developed by Mitsubishi Electric with the following features in order to respond to customers’ maintenance demands.

### [1] Compact

GenSPIDER® is designed to travel in the air gap to perform accurate inspections. Thanks to a proprietary traveling mechanism comprising a crawler belt and flat plate, GenSPIDER® has the advantage of a thin **19.9-millimeter profile. It is capable**

**of inspecting most Mitsubishi Electric mid- and large-sized generators and Non-Mitsubishi Electric generators.** Conventional robots cannot be applied to some of Mitsubishi Electric’s generators due to the air gap size.

### [2] Quantitative Approach to Wedge Tapping

GenSPIDER® can accurately ascertain wedge tightness across a full range: very tight - moderate - very loose. The tapping test uses original vibration analysis technology to accurately detect five levels of stator wedge tightness. As a result, GenSPIDER® is able to evaluate stator wedge looseness, **as equivalent to an inspection carried out by hand, and to detect early stages of**

**stator wedge looseness.** By comparison, the conventional robot is able to fully evaluate “tight” and “loose”, however does not have sufficient capability to distinguish “moderate”. A classification comparison of stator wedge tapping between GenSPIDER® and the conventional robot is shown in Figure 1.

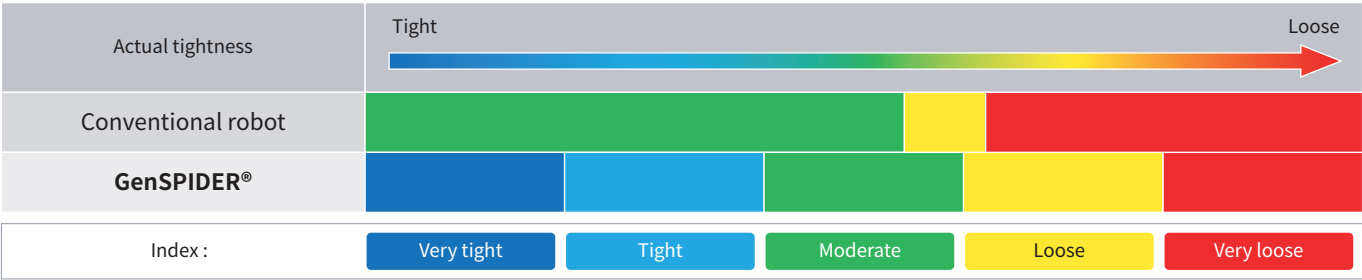


Figure 1. Classification of Stator Wedge Tapping

### [3] Outage Duration Reduction

After a generator enters a periodic inspection, it is very important that customers quickly assess the generator condition so the unit can be returned to service as fast as possible. GenSPIDER® can provide a solution to reduce the outage duration.

Table 1 lists each inspection part and the items of typical generator-related inspections compared with “ADVANCED” simplified inspections carried out by GenSPIDER®. The Advanced

Simplified inspection covers similar generator inspection items to the Major inspection, as opposed to the Simplified inspection. In addition, **a generator rotor does not need to be pulled out for an inspection by GenSPIDER®**. Therefore, the robotic inspection can be completed within the time period of a minor inspection. As the result, **outage duration is shortened and customers can restart operation of the generator earlier than with other inspections.**

Inspection Part	Inspection Item	Inspection Category		
		Simplified	Advanced Simplified by GenSPIDER® Package	Major
Stator End Winding	VI	✓	✓	✓
Stator Winding in the Slot	VI		✓	✓
	Trapping for Wedges		✓	✓
	ET	✓	✓	✓
Stator Core	VI		✓	✓
	EL-CID		✓	✓
	IR for Through Bolt	✓	✓	✓
Rotor Shaft	VI		✓	✓
	NDT for Wedges		*	✓
	NDT for Retaining Ring		*	✓
	Center Bore Leak Test			✓
Rotor Winding	VI		✓	✓
	ET	✓	✓	✓
Rotor pulling out		Not required	Not required	Required
Outage duration		1 week	1 week	1.5 months

VI : Visual Inspection IR : Insulation Resistance Test ET : Electrical Test NDT : Non-Destructive Test \* : Will be released in near future

Table 1. Inspection Parts and Items of each Inspection

### [4] Two Inspectors

To implement a robotic inspection by GenSPIDER®, **only two Mitsubishi Electric TAs (inspectors) are required.**

- **Inspector A : Operator**

Operates GenSPIDER® and carries out tests with Robot Control Unit outside of the generator.

- **Inspector B : Installer**

Installs GenSPIDER® into the air gap on each slot inside of the generator.

Disassembly of generator small parts such as manholes and endbells is required to allow inspectors access to the generator. The number of disassembly parts is different according to each generator's design.

The respective positions of the inspectors are shown in Figure 2.

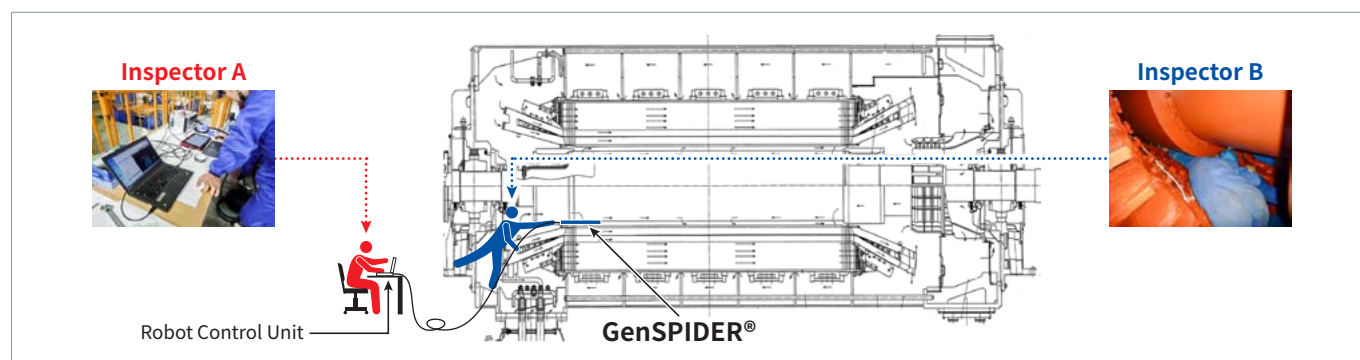


Figure 2. Positions of Inspectors for Robotic Inspection



### 3. Benefits

Robotic inspection by GenSPIDER® gives customers the following benefits.

#### (1) Condition Based Inspections vs Calendar Based Inspections

Customers can carry out GenSPIDER® inspections regardless of turbine inspection type. Because the GenSPIDER® inspection only requires a one week generator outage, it is possible to complete the GenSPIDER® inspection even within the

combustor inspection period. Therefore, **customers can implement robotic inspections more often and accurately ascertain the interior condition** as well as detect abnormalities in the short term.

#### (2) Maintenance Cost Reduction

Frequent interior condition monitoring enables customers to plan appropriate periodical inspection schedules. This leads to **shortening of the inspection period and reduction of loss** due to generator outage. Carrying out periodical inspections at

the right timing means continuous avoidance of forced outages. Preparing necessary spare parts prevents the occurrence of extra expenses and unexpected extensions of outages for major inspections with the rotor pulled out.

#### (3) Accurate Trouble Shooting and Planning Future Maintenance

Robotic inspections by GenSPIDER® can provide valuable information as to the condition of the generator without the need for costly rotor out inspections. This information can be

used to **plan corrective maintenance in more depth** while lessening the probability of in-service failures.

## 4. Robotic Inspection Capabilities

Contents of the inspection and examples of the results are shown below:

### [1] Visual Inspection

GenSPIDER® is equipped with an LED light and a tilted mirror which can be rotated 360 degrees in front of the remote camera installed in an axial direction. This way the GenSPIDER® is able to **take clear images of the stator and rotor** in a 180 degree position, even in the dark inside the generator. The Remote

Camera can inspect the rotor ventilation hole and the stator core bore surface **without rotor removal**. Early detection of any abnormalities is essential in order to discover issues present before they result in major failures. Examples of detected abnormalities are shown in Figure 3.



Figure 3. Examples of Detected abnormalities

## [2] Stator Wedge Tapping

Stator Wedge Tapping can be used to check the wedge tightness without the rotor being pulled out. The tapping mechanism of GenSPIDER® consists of three components: a hammer which vibrates the stator wedge, a motor which drives the hammer, and an accelerometer which detects vibrations on the stator wedges. GenSPIDER® is also equipped with a cam mechanism. Installing the cam driving motor axially on GenSPIDER®'s body results in a thinner body and assurance of sufficient vibration torque. As a result, GenSPIDER® is currently applied to many kinds of generators, providing accurate measurement of stator wedge

tightness. A wedge tapping schematic is shown in Figure 4. Traditionally, inspections of degrees of looseness in stator wedges have been conducted by engineers who then judged the results quantitatively. However, **GenSPIDER® quantifies the looseness as numerical data**. Accumulating inspection results and analyzing trends enable customers to **evaluate the condition of components in stator core slots**. From these results, the number of required spare wedges can be prepared in advance of the next outage. Results of a stator wedge tapping inspection are shown in Figure 4.

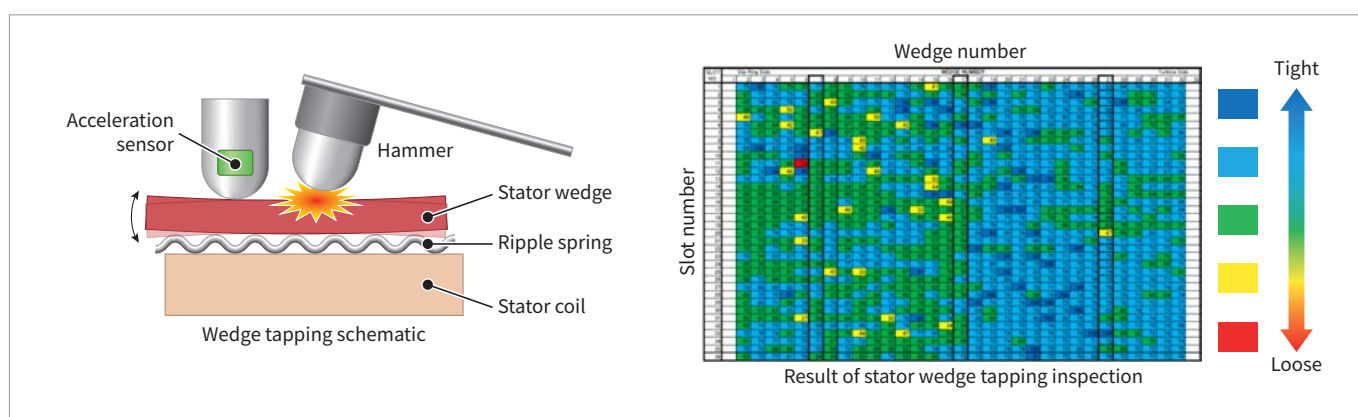


Figure 4. Wedge Map (stator wedge tightness distribution)

## [3] EL-CID

The EL-CID (Electromagnetic Core Imperfection Detection) test is used to determine the integrity of the inter-laminar insulation in the stator core and identify underlying eddy-current issues. EL-CID detects the stator core layer short without the rotor being pulled out. **Early detection of stator core abnormalities can**

**help avoid serious accidents, and it can be effective in identifying core issues prior to major damage during operation.** An image of an EL-CID test and an example of a detection of layer short are shown in Figure 5.

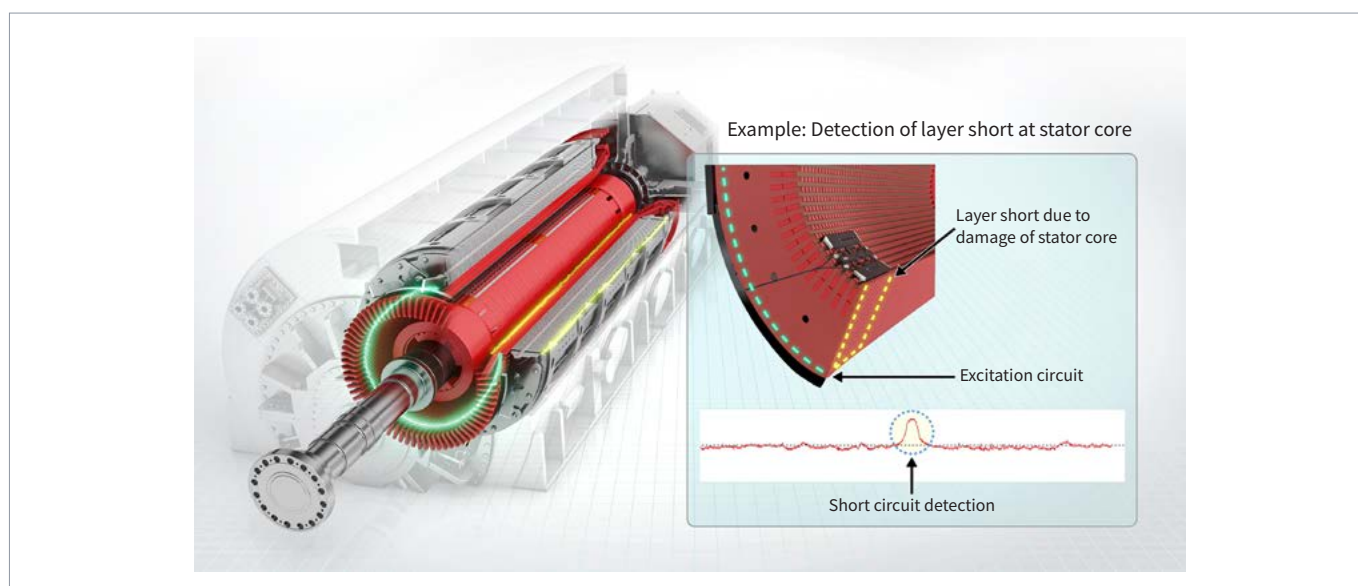


Figure 5. EL-CID Test

5. Robotic Inspection Equipment

Main equipment and tools of robotic inspection - Figure 6 and 7.  
Detailed specifications of GenSPIDER® - Table 2.

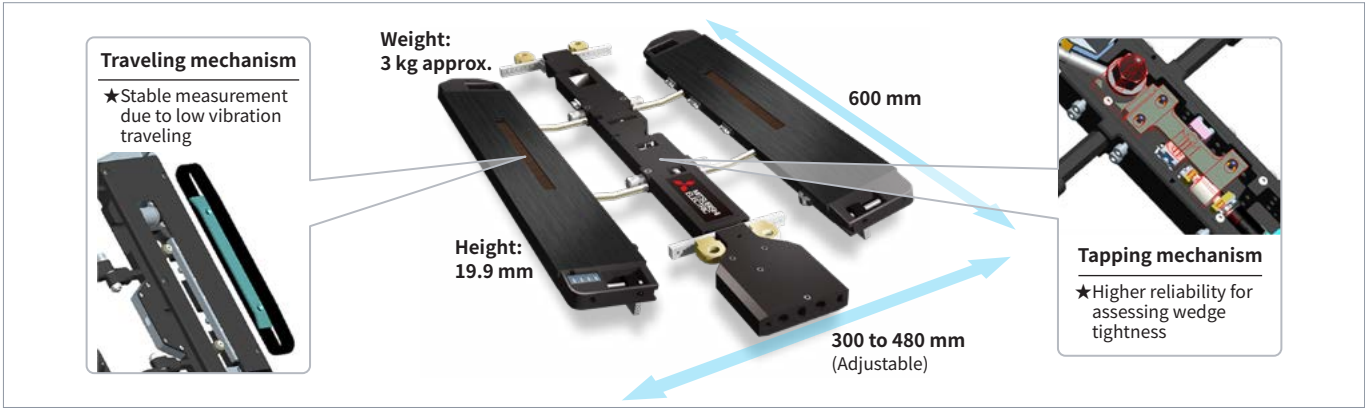


Figure 6. Exterior of GenSPIDER®



Figure 7. Exterior of Inspection Tools

Robot Dimension	Length	600mm [23.6 in]
	Width	300 to 480 mm [11.8 to 18.9 in] (Adjustable)
	Height	19.9mm [0.78in]
Robot Weight		3kg [6.6 lbs]
Operating Temperature		-10 to 50 °C [14 to 122 °F]
Power Supply		AC 100V to 240V (50Hz/60Hz)

Table 2. Specifications of GenSPIDER®

(1) GenSPIDER®

GenSPIDER® has a remote camera, stator wedge tapping and traveling mechanism. It runs axially on the generator stator core and conducts inspections.

(2) Robot Controller

The robot controller controls the remote camera, stator wedge and traveling mechanism in GenSPIDER® through a cable connected to GenSPIDER®.

(3) PC for Monitoring and Data Storage

Remote camera images, as well as stator wedge tapping and EL-CID test results are shown on the Monitoring PC. Results of each inspection are saved digitally.

(4) Robot Control Unit

Robot control unit converts stator wedge tapping signals from analog to digital and supplies electricity to the GenSPIDER®.

(5) EL-CID Unit (Option)

The EL-CID unit excites the generator stator core and controls EL-CID testing.



## 6. Summary

- **Robotic inspections enable frequent generator interior inspection to be implemented within a short period without rotor removal.** Mitsubishi Electric offers subsequent future maintenance and recommendation work for the customer’s next inspection depending on the results.
- GenSPIDER® is compact and can be applied to **most Mitsubishi Electric and Non-Mitsubishi Electric Generators.**
- GenSPIDER® capabilities
  - (1) Visual Inspection
  - (2) Stator Wedge Tapping
  - (3) EL-CID Test

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# Mitsubishi Electric Generator Robotic Inspections

## “GenSPIDER®”

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\*GenSPIDER is a registered trademark of Mitsubishi Electric Corporation in Japan and USA, and is a trademark of other countries.



### Safety information

- Carefully read the operating instructions before using and use only as specified.

In accordance with the Foreign Exchange Act, the export of strategic materials (or services) included in this product requires an export (or service transaction) license from Japan's Ministry of Economy, Trade and Industry.



### ISO 9001 Certified

This product has been designed and manufactured under a quality control system corresponding to ISO 9001, the international standard for quality control systems.