Development of a New Point Machine for the Next-Generation Turnout

ES-type point machines (commonly called “next-generation point machines”) have achieved improved operability thanks to reduction of weight and number of parts that require adjustment. Approx. 260 units of this type of point machine have been deployed since 2002. While we have made mechanical and programming improvements in the time since deployment started, the machine still has some issues in lightning and water resistance and restrictions in terms of the environment where it can be used. At the opportunity presented by further deployment of next-generation turnouts, we have drawn up concepts such as those for securing safe and stable operation, simplifying installation and maintenance and extending the usage environment. A new point machine for the next-generation turnout (ESII-type) has thus been developed based on those concepts.

We have confirmed that the developed machine meets the required specifications in performance evaluation tests. This article covers an overview of the ESII-type point machine, its point accessories and monitoring devices and the test results.

Keywords: Next-generation point machine, Lightning damage countermeasures

1 Introduction

1.1 ES-Type Point Machine

ES-type point machines (hereafter “ES-type”, Fig. 1) have been introduced since 2002 as the point machine for the 2000-type turnout (commonly called “next-generation turnout”). That point machine has achieved improvements in ease of installation and maintainability with the following advantages.

(1) Rods consolidated on sleepers, making mechanized tamping at turnouts using a switch multiple tie tamper possible.
(2) Thorough downsizing (approx. 99 kg, less than 1/3 of the weight of the NS-type)
(3) Improved point fixing and locking adjustment work by adopting LED display and check gauge (Fig. 2)
(4) Remote data monitoring (monitoring function) such as failure output and switching force as a standard feature

Fig. 1 ES-type Point Machine

1.2 Issues of ES-Type

Approx. 260 ES-type machines have been deployed while undergoing both mechanical and programming improvement. However, they still have the following performance issues and restrictions in use conditions.

(1) Performance Issue

We have added a lightning resistant transformer to the machine as a lightning damage countermeasure, improving lightning resistance to approx. 9 kV. Nevertheless, there is already evidence that the probability of suffering lightning damage can be lowered to 1/10 or less by improving the lightning resistance to 30 kV. Securing 30 kV lightning resistance is thus desirable from a standpoint of stable transport in the greater Tokyo area.

On top of that, ES-type machines are not waterproof. Water resistance to endure temporary immersion is also desirable.

(2) Restrictions in Usage Environment

ES-type machines are not used for curved turnouts in the same/opposite directions (turnouts in cant sections), in cold regions (temperatures less than -10°C) and in AC-electrified sections.

As further deployment of the 2000-type turnouts is expected, we have developed a new point machine (hereafter “ESII-type”) with an aim of solving the above-mentioned issues and restrictions while inheriting the advantages of the ES-type explained in section 1.1.

Fig. 2 Support to Locking Adjustment by LED Display and a Check Gauge

2 ESII-Type Point Machine

2.1 Specifications and Advantages

We studied the specifications and structure for the ESII-type with an aim of solving the issues and restrictions that came to light with the ES-type while inheriting its advantages. The following describes the new concepts for the ESII-type and the major specifications achieved with the ESII-type to achieve those concepts. The appearance is shown in Fig. 3.
2.1.1 Securing Safe and Stable Operation

(a) Improvement of Lightning Resistance
A lightning resistant transformer and an arrester with a deterioration indicator are incorporated into the ESII-type machine. The machine is grounded to the rail with an equipotent bar as well to transfer lightning surge to the rail (Fig. 4). Those measures have improved lightning resistance from approx. 9 kV (with a lightning resistant transformer) of the ES-type to 30 kV.

(b) Improvement of Water Resistance
We have improved water resistance of the machine by adopting a watertight structure. While IPX7 water resistance (not damaged by temporary immersion) was secured for the ESII-type, the degree of water resistance with the ES-type is only IPX4 (protected against splashed water). Fig. 5 shows the ESII-type machine in an submerged test.

(c) Failure-resistant Switching and Fixing Mechanism
The switching and fixing device of the ESII-type employs a gear mechanism because of the mechanism’s good track record (Fig. 6).

(d) Point Indicator Output at Control Failure
By adopting a switching control relay and a circuit controller, the ESII-type machine can output the point route direction of the turnout to the interlocking device, which has improved continuity of train operation (Fig. 7).

(e) Prevention of Errors in Switching and Indication
A motor power circuit breaker has been built in. This cuts power supply to the motor while the machine is not switching.

(f) Securing Allowable Turnout Displacement
We have secured the maximum switching torque (approx. 4 kN) with a margin in relation to track irregularity (height difference between rails, unaligned toes of tongue rails).

2.1.2 Simplification of Installation and Maintenance Work

(a) Left-and-Right Compatibility
We have made the structure of the point to allow installation either to the left or the right of the turnout (left-and-right compatibility). Conventional points such as the NS-type need replacement of main and sub lock rods when changing the installation position of the point, and the ES-type has a structurally separate left version and a right version to avoid on-site lock rod replacement. In contrast, the ESII-type can be installed either on the left or the right side without replacing the main and sub lock rods because it has joint fixtures both on the left and right sides of the lock rods. To allow the lock rods to be connected either on the left or the right side, the joint fixtures have different shapes for the left and the right (Fig. 8). This improvement has allowed for a reduction in replacement spares that need to be kept.


2.1.3 Design for Longer Life and Environmental Friendliness

(a) Components Replaceable On-site

As the ES-type point machine is sealed, it needs to be entirely replaced in case of a failure, regardless of what component the problem lies in. In contrast, the openable point machine cover of the ESII-type allows replacement of components inside of the machine, even though the machine as a whole is sealed watertight. We have thus achieved a reduction in failure down time and maintenance costs. Fig. 11 shows on-site replaceable internal components.

(b) Implementation of Overhaul at Manufacturers

Overhauls extend the life of the point machine.

2.1.4 Expansion of the Usage Environment

(a) The machine can be used for turnouts curved in the same/opposite directions (turnouts in cant sections with a maximum cant of 70 mm). Fig. 12 shows a switching test at 70 mm cant.

(b) The temperature range for use has been extended to -20°C/+60°C. The ESII-type point machine can thus be restored to operation by simply replacing those components.

(b) Implementation of Overhaul at Manufacturers

Overhauls extend the life of the point machine.

(c) A model with 3.5 second switching time has been added to the standard five-second switching model. The faster model can handle timetables that need quick switching.

(d) Usable in AC-electrified Sections

The effects of induction on the ESII-type are contained by being grounded to the rail with an equipotent bar.

(b) Prevention of Faulty Work

To eliminate wiring work inside the point machine, we have made wiring changeable by changing jumper leads. To prevent plugging errors, each jumper lead has distinguishable color and shape (Fig. 9). As an external improvement of the point machine (signal house and cabinet), the same single pin assignment has been adopted regardless of the installation position and normal route direction.

(c) Operability Improvement

In order to improve operability, the structure of the button and manual handle that are used for switching in maintenance and inspections have been changed to allow operation from the top of the point machine housing (Fig. 10).

(d) Easy-to-understand Monitor Display

An easy-to-understand monitor display that is an advantage of the ES-type has been inherited by the ESII-type. That makes the display compatible with that of the ES-type.
Table 1 shows a comparison between the NS-type, ES-type for 2000-type turnouts and the ESII-type developed this time. With the ESII-type, we have improved lightning and water resistance and broadened the usage environment. That was done while keeping the strong points of the ES-type including compatibility with the 2000-type turnout, use of a servomotor and enhanced monitoring functions.

<table>
<thead>
<tr>
<th>Table 1 Comparison between Point Machines</th>
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<tr>
<td>NS-type</td>
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<td>2000-type turnout compatibility</td>
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<tr>
<td>Motor and switching force transmission</td>
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<tr>
<td>Power supply</td>
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<tr>
<td>Use in cold, cold regions, AC electrified sections</td>
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<td>Monitoring function</td>
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<tr>
<td>Lightning resistance</td>
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<td>Water resistance</td>
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2.2 Performance Evaluation Test
We carried out performance evaluation tests to confirm that the above-mentioned specifications and structures meet the required specifications. The following are the details and results of the main tests.

2.2.1 Change of Temperature Testing [JIS E 3020 Type 6]
We placed test samples in constant-temperature baths at -30°C and +60°C alternately for three hours or longer. This process was repeated five times. We confirmed that correct switching was done and no servomotor defects were detected on the monitor. After the tests, no air leaks were detected in air-tightness tests and no abnormalities in the external appearance and inside were found.

2.2.2 High and low Temperature Testing [JIS E 3019 Type 5]
We set a more severe standard temperature range of -20°C to +70°C than the JIS standard temperature range of -20°C to +60°C. As for placement time, we left the test sample until the internal temperature completely converged (approx. 10 hours at the lower temperature, approx. 30 hours at the higher temperature), while the JIS standard specifies two hours. After that, correct operation was confirmed (Fig. 13).

Furthermore, correct operation of the button switch was confirmed by repeatedly pressing the switch at -20°C (Fig. 14).

2.2.3 Vibration Test [JIS E 3014 Type 3-B]
Shock Test [JIS E 3015 Type 4]
The test conditions of those tests are shown in Table 2.

<table>
<thead>
<tr>
<th>Table 2 Conditions of Vibration Test and Shock Test</th>
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<tr>
<td>Test</td>
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<tr>
<td>Functional test to resistance and vibration</td>
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<tr>
<td>Vibration durability test</td>
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<tr>
<td>Power</td>
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We supplied electric power to the power source for the motor and the indicators while shaking the test sample. Through the tests, we confirmed that no instantaneous interruption of route indication occurred and no failure information was displayed on the monitor.

After shaking in the specified directions, correct switching was confirmed.

Some parts were damaged and a monitor transmission error occurred in the vibration tests. We thus carried out the tests again after some improvements to those, and we successfully confirmed that there were no errors.

2.2.4 Lightning Resistance Test
(1) Confirmation of Voltage Resistance Target
Based on confirmation that voltage resistance of the motor driver, an electronic device, was 10 kV, we set the voltage resistance target for the power supply line and control cables to be 10 kV when a lightning surge is applied.

(2) Comparison between Countermeasures for Control Cables
We compared a DC 3.5 kV protective device, DC5.5 kV protective device and 1.0 mm air-gap, finding that the voltage at the control cables exceeded 10 kV with a DC 5.5 kV protective device and a 1.0 mm air-gap. We thus decided to employ a DC 3.5 kV protective device. The specified dielectric strength voltage of the DC 3.5 kV protective device is DC 3.5√2x 0.8%AC 2.0 kV even taking ± 20% into account. That means we have achieved the target value AC 1.5 kV or more.
(3) Protective Device Characteristic Check
We developed a protective device with DC 3.5 kV voltage resistance and with a deterioration monitor, and we checked the characteristics of that in actual installation. At applying voltage up to 30 kV, we confirmed that voltage at the control cables did not exceed 10 kV.

(4) Collective Voltage Application Tests
We carried out tests where a lightning surge was applied to all cables at once of the test sample in operation. The test results proved that no problems occurred at applying 30 kV voltage.

(5) Induced Lightning Surge Test
We carried out a test where induced lighting was applied to cables in operation and confirmed that no problems occurred at applying 30 kV voltage. Then, in the limit test, we confirmed that no problems occurred at applying 50 kV.

Fig. 16 shows the lightning resistance test.

2.2.5 Continuous Switching Tests [JIS E 3001]
We installed an ESII-type point machine to a larger next-generation turnout (number 16 for 60 k r ail) at 70 mm cant, and we carried out continuous switching tests for switching times of 3.5 seconds and 5 seconds. The JIS requirement is 220,000 instances for manual switching tests regardless of the life span. The ESII-type is, however, specified to be overhauled per 400,000 instances of switching in this test. We thus carried out more than 600,000 instances of switching, 1.5 times more than the specification. The test results demonstrated that no problems occurred during the test. After the continuous switching test, we carried out a disassembly check. No abnormalities were found at any components (Fig. 17).

Fig. 17 Continuous Switching Test

2.2.6 EMC Tests [IEC62236-4-2, 3, 4, 8, 9]
In accordance with the IEC standard, we applied to the ESII-type point machine radiated RF electromagnetic fields, power-frequency magnetic fields, electrostatic discharges, voltage dips/instantaneous interruptions, fast transient bursts, conductive electromagnetic fields, rail conductive electromagnetic fields, impulses and rail impulses. The test results showed no effect on the machine (Fig. 18). Taking into account actual use, we further carried out electromagnetic field tests using a transceiver and observed no effects.

Fig. 18 EMC Test

2.2.7 Waterproof Tests [JIS E 3017 D (a)] [JIS C 0920 (IPX7)]
In accordance with the JIS standard, we placed the ESII-type point machine in a water tank with the bottom of the machine at a depth of greater than 1 m. No water intrusion was found after leaving the machine in the water for 30 minutes. As a test more severe than that of the JIS standard, we further carried out 10,000 instances of switching and manual switching underwater and 3,000 instances of switching in muddy water. Correct operation and no water intrusion were confirmed (Fig. 19).

Fig. 19 Submergence Test

2.2.8 Intentional Abuse Tests
We carried out intentional abuse tests such as inserting foreign materials into mechanical parts, hammering while in operation, disconnecting cables in operation, testing handle switch durability, applying upper/lower limit voltage and applying overvoltage. No unusual operation was observed in any of the cases.

Rails carry a signal current of the track circuit to detect trains in the track section. When left and right rails are short-circuited, the track circuit detects a train in that track section. Fig. 20 shows electric connections of the ES-type point machine and the ESII-type point machine respectively in different texture patterns.

Fig. 20 Electric Connection between Point Machine and Rails
As a countermeasure against lightning damage, the ESII-type is electrically connected to one of the rails to transfer lightning surge to that rail. Accordingly, the point machine and the front rod are equipotent to that rail. The angled hinge of the front rod is insulated. That angled hinge is also used for the NS-type and other conventional point machines without problem in normal conditions. But, if conductive foreign material such as an iron fragment is present, that fragment might electrically connect the front rod to the rail on the other side of the point machine. That would cause the track circuit to misdetect a train. We thus enhanced the insulation of the angled hinge of the front rod compared to the ES-type. Fig. 21 is a photo of the improved insulated part of the front rod.

Fig. 21 Insulated Part of Front Rod for ES-Type and Improved Insulated Part of Front Rod for ESII-Type (right)

The improved front rod is also used for the ES-type point machine. In order to prevent accidental misuse, we have unified the specifications for the improved front rod both to be used for the ES-type and ESII-type point machines.

4 Monitoring Device

The ES-type point machine has a monitor as standard equipment that accumulates switching data and judges and outputs failure information. This has been making great contributions in areas such as maintenance work and cause investigation in case of failure occurrence. The ESII-type has inherited this advantage and has been further improved. Specifically, it has the same configuration as the ES-type (monitor data converter, monitor processor and monitor display) to handle both the ES-type and the ESII-type being used in parallel. Fig. 22 shows photos of each monitor component.

Fig. 22 Components of Monitoring Device for ESII-Type

The characteristics of the monitor are as follows.

1) The ESII-type has the same hardware configuration as the monitor for the ES-type (monitor data converter, monitor processor and monitor display).

2) Basic functions of the software (accumulating switching data, outputting failure information, communicating with the steady state monitoring system) are also the same as the monitor for the ES-type, so it is possible to monitor both the ES-type and the ESII-type used in parallel.

3) The monitor for the ESII-type added function to record switching data whenever receiving switching control signals, even without actual switching (switching data also recorded at ES-type point machines used in parallel in the field for monitoring), having increased opportunity for recording switching data in switching disruptions. That could contribute to discovering the cause of disruptions.

Fig. 23 shows a sample screen of switching data.

Fig. 23 Sample Screen of Switching Data

5 Future Plans

The first unit of the ESII-type point machine was put into actual use at Kawasaki freight station in July 2010. As the first test lot, we introduced that machine at five locations including Kawasaki freight station, and those are operating well. As the next step, we are introducing the point machine to five more locations. The machine will be gradually introduced to service based on later operation status.

In the future, we will develop based on this point machine a point machine for next-generation turnouts that can be used in the network signal control system. Research on rated value control based on the monitor data is also being conducted.

6 Reference