Technology Improving Servo Amplifier Reliability

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1. Introduction

Servo systems are required to maintain their function and performance without failure or faults the entire time during customer's machinery and equipment is in operation. However, there are cases of the product failure due to damaged or deteriorated componets by some causes and cases of the motor stop due to detect a fault caused by equipment-side related factors such as failure of external components.

When the motor stops due to product failure or fault detection, the system also stops and the plant manufacturing lines are impacted heavily. Moreover, if a component related with a safety function is failing, there is an increased risk of human casualty.

As such, it is important to make servo motors robust and safe as well as perform preventative maintenance to be able to detect failures before they escalate into a system down. Moreover, assuming a fault did occur, it is necessary to identify the cause and solution early so as to minimize the down time.

With consideration to this point, this report will introduce the following technologies to improve servo amplifier reliability that Sanyo Denki is involved in.

(i) Improving robustness against power noise
(ii) Improving safety performance of the "Safe Torque Off" function
(iii) Technology to detect deterioration of motor insulation
(iv) Troubleshooting support technology

2. Improving Robustness Against Power Noise

In line with the globalization of recent years, Sanyo Denki's servo systems are also being used in many countries with a focus on SE Asia. The power situation of most of these countries is different to Japan's, with large voltage fluctuation and surge voltage, which are some of the reasons behind erroneous servo amplifier operations and damage to internal electronic components. This section provides an explanation on technology to improve the robustness of servo systems against power noise.

The various types of power noise are normal mode noise generated between power lines, common mode noise generated between power lines and housing grounds and induced lightning surge caused by lightning (hereinafter "lightning surge"). From the angle of the servo amplifier, lightning surge enters as common mode. Also, compared with normal/common mode noise, lightning noise generates much higher voltage and energy causing erroneous servo amplifier operations and damage to internal electronic components. Generally speaking, a countermeasure for lightning surges is connecting a commercially-sold surge protector to the servo amplifier's input power, however the additional cable work is required and there are other issues such as securing installation space, etc. As such, Sanyo Denki has installed lightning surge countermeasure components on the printed circuit board (PCB) inside the servo amplifier as a technology to prevent erroneous servo amplifier operations and damage to internal electronic components without increasing the cabling.

We have set up a lightning surge countermeasure circuit between the power line nearest to the input power connector of the PCB and the housing ground in order to limit the lightning surge voltage that enters into the servo amplifier. Fig. 1 and 2 show waveforms of the voltage impression between the servo amplifier power line and housing ground created when 5 kV was applied using a lightning surge tester in order to make a comparison. Fig. 1 shows the waveform of the voltage impression created in the case of no lightning surge countermeasure circuit, while Fig. 2 shows the waveform with a lightning surge countermeasure circuit.

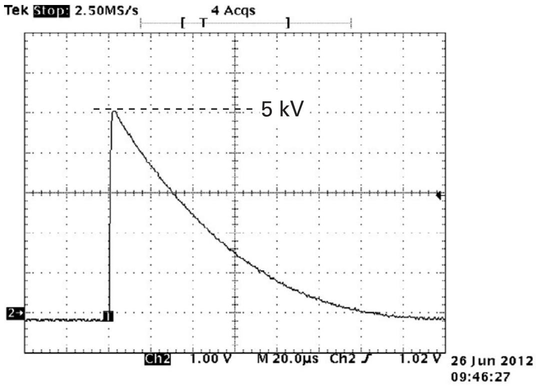

Fig. 1: Voltage impression when there is no lightning surge countermeasure circuit

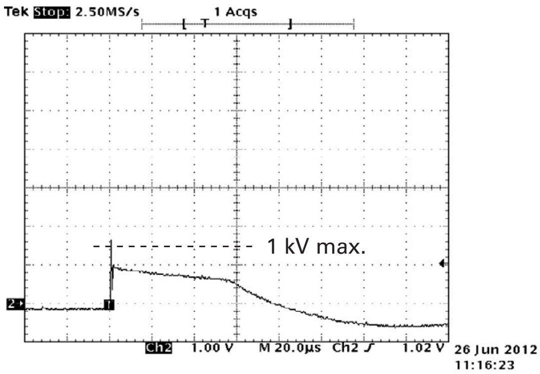

Fig. 2: Voltage impression when there is a lightning surge countermeasure circuit

If a lightning surge countermeasure circuit is used, the voltage impression can be restricted to 1 kV or less. This prevents erroneous servo amplifier operations and damage to internal electronic components, as well as improves robustness towards power noise.

3. Improving Safety Performance of the “Safe Torque Off” Function

The Safe Torque Off function is a control function which stops current to the servo motor and turns torque off in order to secure safety in the event that an input signal (2 channels) has been received from a safety device such as an emergency stop button or light curtain.

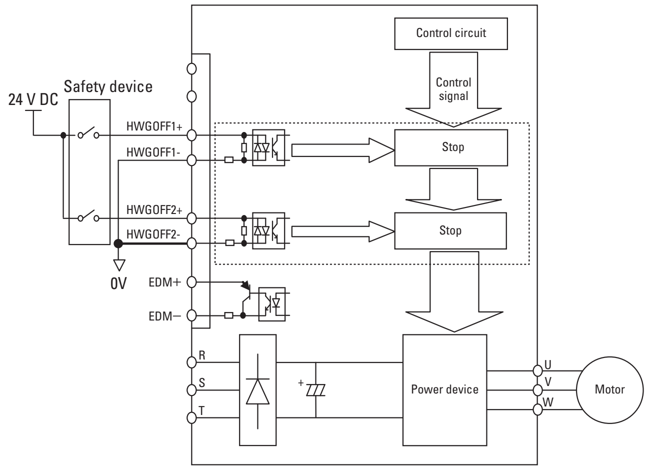

Fig. 3: Safe Torque Off circuit block diagram

This function has been equipped on Sanyo Denki's products since the “SANMOTION R Advanced Model” (hereafter “RS2 Servo Amplifier”) and the main functional safety standards and safety performance are as shown in Table 1.

Table 1 Standards which the RS2 Servo Amplifier complies with

Item	Standard
Safety function	IEC61800-5-2, Safe torque off IEC60204, Stop category 0
Functional safety standard	ISO13849-1, PL=d IEC61508, SIL2 IEC62061, SILCL2 EN954-1, Cat.3

In general industrial device application, this safety performance is satisfactory, however, in the case of medical equipment such as MRI (magnetic resonance imaging) and CT (computed tomography), a higher level of safety performance is demanded.

Therefore, in order to improve the Safe Torque Off function developed on the RS2 Servo Amplifier, Sanyo Denki is engaging in activities to comply with the PL “e” (safety performance level) of ISO 13849-1 (Safety of Machinery — Safety-related Parts of Control Systems) and the SIL “3” (safety integrity level) of IEC61508 (Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems).

Taking ISO13849-1 as an example, the safety performance level (PL) is determined by factors such as system architecture (Cat.), meantime to dangerous failure (MTTFd), and the diagnostic coverage (DC). In order to increase the safety performance level, reducing dangerous-side failure rate and improving dangerous-side failure detection are specially important. The below graph shows the relationship between the ISO13849-1 safety performance level, category, MTTFd and DC.

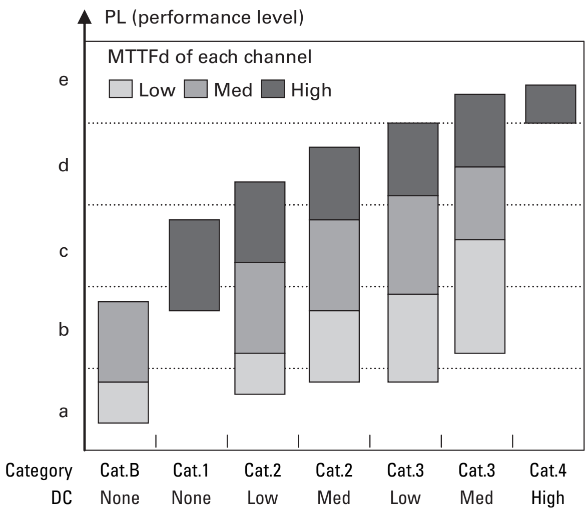

Fig. 4: Relationship between category, DC, MTTFd and safety performance. (ISO 13849-1)

The improvement of safety performance contributes to reducing the risks when people directly work near the moving parts of machines, as well as improves machine reliability (safety).

4. Technology to Detect Deterioration of Motor Insulation

One of the applications of servo systems is on machine tools. Machine tools perform machining while using coolant, and if this coolant adheres to the motor, depending on the coolant type, it may infiltrate the motor and deteriorate the motor insulation. Motor insulation deteriorates gradually until it finally leads to a ground fault. Ground faults of the motor will trip the leakage breaker or damage the servo amplifier. This section introduces a preventative maintenance technology to detect deterioration of motor insulation before this kind of unwanted situation occurs.

Insulation resistance testers are commonly used to measure the deterioration of motor insulation. This method involves removing the motor cable, measuring the motor insulation resistance with the tester and judging the motor insulation is deteriorated or not by comparing with a threshold value. Generally, machine tools are equipped with more than one motor, therefore in order to check one machine, the cables of the motors for each axis must be removed, insulation resistance measured, then, once measurement is complete, the cables need to be reconnected. This requires many man-hours. As such, Sanyo Denki has developed a technology to determine insulation deterioration by detecting the insulation resistance using a servo amplifier.

Normally, servo amps are connected to 3-phase AC power through an electromagnetic contactor. Inside the servo amplifier, this 3-phase AC power under goes full-wave rectification through a rectifier circuit to be outputted as DC voltage. This is smoothed in an electrolytic capacitor, then converted back to AC using a PWM invertor and used to drive the motor. Fig. 5 shows an amplifier for machine tools. An insulation deterioration detection circuit is set up on the servo amp inverter and serves the purpose of detecting deterioration of motor insulation. When insulation deterioration is detected, the electromagnetic contactor is turned off to isolate power, the inverter is driven and a set amount of voltage is applied to the motor. Motor insulation resistance is then detected by detecting the current which has leaked through the motor insulation resistance to the insulation deterioration detection circuit. Then, if the insulation resistance drops below the specified value, insulation deterioration will be detected and motor replacement is required. Normally, motor insulation resistance should be 100 MΩ or more, however this decreases to around 2 MΩ as the insulation deteriorates. This state is then detected as insulation deterioration and encourages motor replacement.

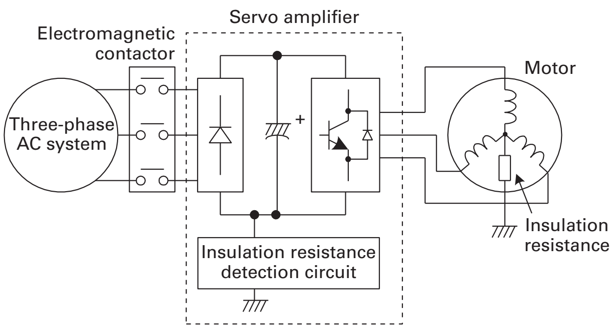

Fig. 5: Motor insulation resistance detection

Through this technology, it is possible to detect failure and perform preventative maintenance before the motor insulation deteriorates and the system crashes, thereby avoiding the need to stop the manufacturing line.

5. Troubleshooting Support Technology

If the servo amplifier detects a fault or does not make the motions intended by the motor and detects a fault on the upper controller side, etc., the motor will stop and the system also will stop. While the system is down, the productivity of the plant drops dramatically, therefore early cause identification and implementation of the appropriate measures are necessary.

However, in order to identify the cause, it is not sufficient to merely know the content of the fault (alarm code, etc.). In such cases, it is necessary to identify the cause through a simulation experiment in either the actual equipment or a similar system, however if the fault is difficult to recreate, it may take many man-hours to identify the cause. Unless the cause is identified and the appropriate measures are implemented, the equipment or system will lose reliability.

In order to solve problems such as this, Sanyo Denki has added a drive recorder function to record the servo amplifier and motor operation status on the servo amplifier for a set period of time. This section introduces this function.

The drive recorder records the motor speed, torque, or the various data such as the main circuit bus voltage, etc., in memory (RAM) at a predetermined sampling cycle, then saves all this data to a nonvolatile memory if an alarm, etc., occurs. By displaying this data as waveforms using a setup software tool (see Fig. 6), it is possible to analyze motions and status up until fault occurrence.

This drive recorder function enables the speedy identification and refining of the causes of faults, thereby making it possible to implement the appropriate measures and make troubleshooting easy. The result of this is being able to minimize the degree to which equipment reliability is lost due to system downtime.

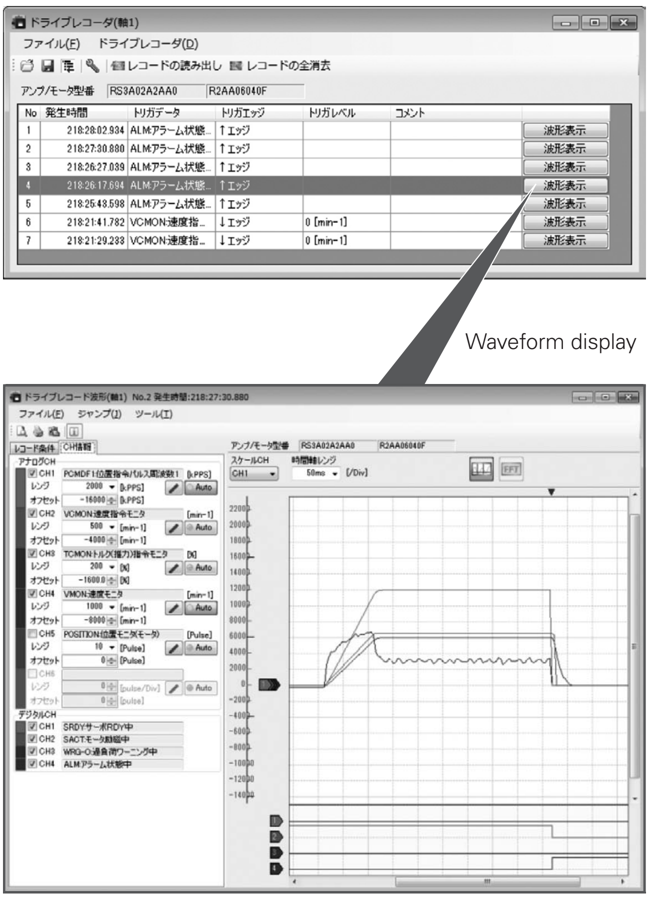

Fig. 6: Drive recorder screen

6. Conclusion

This report has introduced “Improving robustness against power noise” , “Improving safety performance of the Safe Torque Off” function and “Troubleshooting support technology” as technologies that improve reliability of the servo amplifier.

Sanyo Denki plans to provide these technologies appropriately to suit product applications and customer requirements.

It is our intention to continue product development which improves the robustness and safety of servo systems to suit the environments of usage and diversification of requirements amidst globalization of the market, as well as contribute to the improvement in system quality and reliability.

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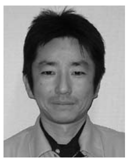

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