Servo Amplifier Technology Contributing to Effective Use of Power

Yuji Ide Masahisa Koyama Haruhiko Chino

Yoshihisa Kubota Michio Kitahara Satoshi Yamazaki

1. Introduction

Motors behave both electric motors and power generators. When motors are rotating, power is consumed, but when motors are rotated, power is generated. (Below, these operations are described as power running and regenerating respectively.) When these motors are used as servo drives and used in applications with relatively low speed acceleration and deceleration repeated, for example, feed axis, regenerative power makes up for a small percentage of the total power. On the other hand, in applications with relatively high speed acceleration and deceleration repeated, for example, spindle axis, regenerative power makes up for a larger percentage of the total power.

There are several methods of handling this regenerative power, including consuming it with resistors, charging it in capacitors, and returning it to power source side.

When it is consumed with resistors, the regenerative power consumed by the resistors is changed into heat and the power is not used effectively.

This document explains technologies for the effective use of regenerative power from motors, mainly focusing on the methods of charging regenerative power in capacitors and returning it to power source side. Furthermore, this document references the reduction of power consumption through controls and outlines energy-saving technologies for Sanyo Denki's motor drives that can contribute to conservation of the global environment in the future.

2. Structure of General-Purpose Servo Amplifiers

Servo amplifiers are normally constructed of a converter from a diode bridge that performs full wave rectification of AC power and an inverter that drives the motor. The inverter is constructed of an IGBT bridge with a free wheel diode and it is constructed for forward/backward conversion.

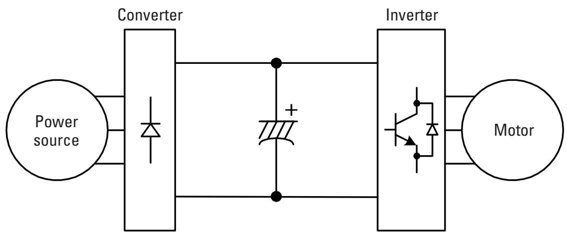


Fig. 1: Structure of the servo amplifier

With this type of structure, when powering the motor, the power source is converted to DC with the converter and after it is smoothed by the smoothing capacitor, it is converted back into AC with the PWM inverter, and the motor is driven.

Alternatively, when regenerating with the motor, the power generated by the motor is backward converted with the PWM inverter and the voltage at the smoothing capacitor is raised. The converter from the diode bridge does not have backward conversion abilities, so when there is a large amount of regenerative power from the motor, the voltage of the smoothing capacitor becomes larger, and when it becomes larger than the withstand voltage for the element, each element is damaged. To prevent this from happening, either end of the smoothing capacitor is attached to a resistor (regenerative resistor) and IGBT. If the voltage from the capacitor becomes larger than the normal value, a process occurs where the IGBT is operated and the regenerative power from the motor is consumed by the regenerative resistor.

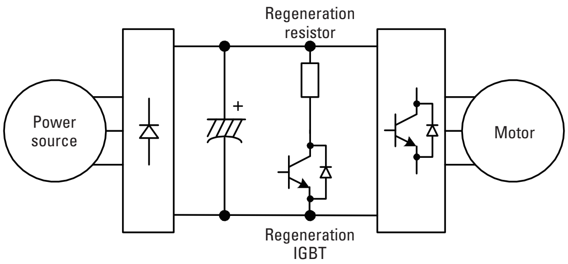


Fig. 2: Processing regenerative electric power through regeneration resistors

3. Effective Use of Regenerative Power with the Common Converter Method

Machines using servo motors are often constructed along many axis like X, Y, and Z axes. So, for instance, if the Z-axis motor is regenerating, the X-axis motor may be power running. The converters for general-purpose servo amplifiers have an independent construction and cannot exchange power between axes, so motor regenerative power cannot be used effectively. On the other hand, with a structure where converters are common and inverters are installed to each axis, power supply is possible from the DC areas and the power from an axis that is regenerating can be used to power another axis.

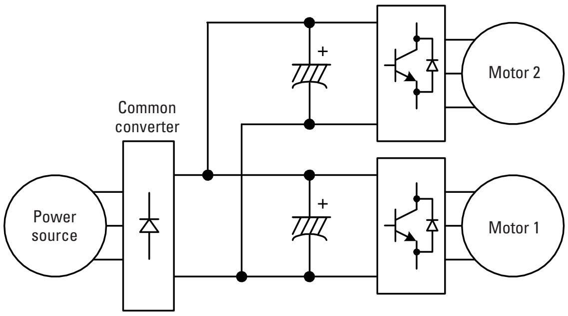


Fig. 3: Servo amplifier structure with the common converter method

4. Effective Use of Regenerative Power with Capacitor Regeneration

In the structure for general-purpose servo amplifiers, adding a smoothing capacitor and increasing capacity enables the smoothing capacitor voltage to be kept at a normal value even during motor regeneration. In this situation, when the motor is generating power, the regenerative power charges the smoothing capacitor, and when power running the motor, the charged power is used to drive the motor. This way, by raising the capacity of the smoothing capacitor, the regenerative power can be reused even in applications with relatively low regenerative power. However, in this method, the permitted voltage rise value for the smoothing capacitor is small, so when there is large regenerative power, the smoothing capacitor capacity may become too large.

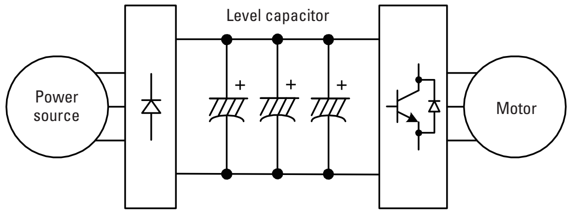


Fig. 4: Processing regenerative electric power through increased smoothing capacitor capacity

To solve this problem, by charging the capacitor using the power converter, the capacitor capacity can be reduced (Documentation 1). With this method, a chopper is used as a power converter, the regenerative power from the chopper is boosted, and the regenerative power charges the regenerative capacitor. In this method, the withstand voltage for the regenerative capacitor is made twice as high as the motor control equipment, and the power stored in the capacitor is used in proportion to the square of the voltage difference, which reduces the capacitor capacity. Compared to simply increasing the smoothing capacitor capacity, this method increases the regenerative power processing performance and enables even more effective use of regenerative power. Furthermore, through appropriate control of discharging the regenerative capacitor, this method can also be used to reduce the peak power.

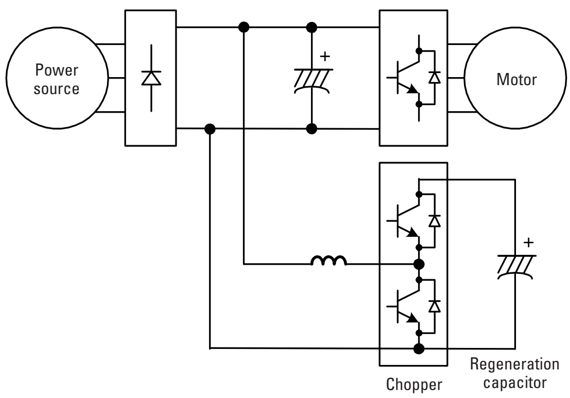


Fig. 5: Processing regenerative electric power using choppers

5. Effective Use of Regenerative Power with Power Regeneration

The method for processing even larger amounts of regenerative power is power regeneration. Power regeneration is constructed of the IGBT bridge along with the free wheel diode in converter side, and it can perform forward/backward conversion. The power generated by the motor charges the smoothing capacitor, and through backward conversion from the converter, the smoothing capacitor power is regenerated as the power source.

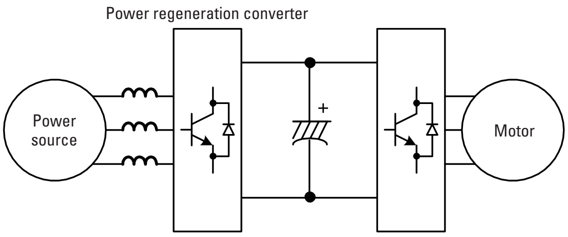


Fig. 6: Processing regenerative electric power through power regeneration

There are two methods for controlling this power regeneration converter: sine wave converter method using PWM control and a simpler 120 degree current method.

The sine wave converter method can turn the power current into sine waves, but it also enlarges power leakage switching noise from PWM operations, which needs an additional filter to suppress. This increases the equipment cost, so servo drives generally use the 120 degree current method.

The 120 degree current method for power regeneration is a method that detects the phase of the power voltage and only regenerates power in a 120 degree interval for the power voltage. Converter switching only needs to occur twice, at the start and stop of the 120 degree interval, so converter IGBT switching loss is minimal. Furthermore, switching is reduced, so power leakage noise is minimized. By detecting the power voltage and the capacitor voltage and controlling the power regeneration operations, power regeneration can be stopped when powering the motor, which can further reduce loss.

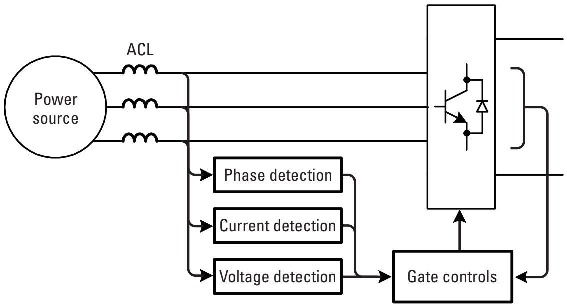


Fig. 7: Power regeneration equipment

Fig. 8 shows the appearance of the RS1 series power unit with power regeneration function that realizes this type of power regeneration.

Fig. 8: Power unit with power regeneration function

This way, by using low power loss power regeneration in the converter, even in applications such as where the motor is continuously generating power, that power can be regenerated in the power source for great efficiency of use for regenerative power. For example, in machine tools that use a spindle shaft, the power consumption can be reduced 50% compared to regenerative power processing with a regenerative resistor.

6. Reducing Power Consumption with High Efficiency Torque Controls of a Synchronous Motor

Spindle axis servo motors have high rotation speed and much larger power consumption compared to feed shaft motors. When powering these spindle axis servo motors, reducing power consumption has a large effect on effective use of power.

Spindle axis servo motors come in various types, including induction motors and synchronous motors.

Induction motors do not use a magnet, which lowers the motor cost, but excitation current must be run through the motor to establish magnetic flux, so the motor power loss is high. On the other hand, synchronous motors use a magnet to establish magnetic flux, so excitation current is not required and the motor loss is low. However, when the motor rotates at high speeds, the magnet-induced voltage on the motor becomes higher, so it is necessary to perform field weakening to reduce the induced voltage. At Sanyo Denki, this field weakening is controlled with the size of torque commands, so unnecessary field weakening is reduced and high efficiency torque controls are applied to the products. With controls that improve motor efficiency while powering the motor, power can be used effectively even when powering.

7. Reducing Power Consumption Through Low Vibrations at the High Speed Driving

For feed shafts, high following controls, model tracking damping controls, suppression functions for minute vibrations due to quantization errors on the encoder, and other such operations can cause large and minute vibrations on the machine. By using functions to suppress these vibrations and realize high speed positioning, the machine's tact time can be shortened and the power consumption while powering can be suppressed.

8. Calling Attention to Energy Savings with a Power Monitor

In control systems that use power regeneration, a function that uses the sensing value to monitor the power in installed, which calls attention to the amount of power consumption for the user using the monitor control equipment. This function helps call attention to effective use of power for not only the servo system, but the entire factory.

9. Conclusion

This document introduced the following technologies that contribute to the effective use of power:

(1) Effective use of regenerative power with the common converter method
(2) Effective use of regenerative power with capacitor regeneration
(3) Effective use of power with power regeneration
(4) Reducing power consumption with high efficiency torque controls of a synchronous motor
(5) Reducing power consumption through low vibrations and high speed driving
(6) Calling attention to energy savings with a power monitor

Sanyo Denki servo systems effectively use these technologies to make products. We put all of our effort into technologies for energy saving, which are essential technologies for conservation of the global environment. In the future, we plan to polish energy-saving technologies even further and provide products with true value.

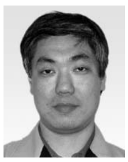
Documentation

(1) Ide, Kikuchi, Koyama: "Regenerative Power Processing Equipment Using Electrolytic Capacitors", 1997 Institute of Electrical Engineers of Japan National Convention, 974 (1997-3)

Yuuji Ide
Joined Sanyo Denki in 1984.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of servo amplifiers.

Masahisa Koyama
Joined Sanyo Denki in 1990.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of servo amplifiers.

Yoshihisa Kubota
Joined Sanyo Denki in 1989.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of servo amplifiers.



Haruhiko Chino
Joined Sanyo Denki in 1983.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of servo amplifiers.

Satoshi Yamazaki
Joined Sanyo Denki in 2001.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of servo amplifiers.

Michio Kitahara
Joined Sanyo Denki in 1991.
Servo Systems Division, 2nd Design Dept.
Worked on the development and design of servo amplifiers.