Control Technology of FRENIC5000VG7S Vector-control Inverter

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1. Introduction

Fuji Electric's high-performance vector-control inverter "FRENIC5000VG7S" series (VG7S) is being used in many applications such as elevators, cranes and winding machines as a special specification product. Even in fields where dedicated controllers and variable speed drive devices have been used in the past, demands for price reduction are resulting in a yearly increase in the number of cases in which systems containing VG7S and other general-purpose inverters are customized and used.

This paper introduces the VG7S's characteristic control technology which is capable of driving induction machines, synchronous machines and DC machines. Also described are example applications that leverage the flexible technology of digital control systems and example applications that utilize the optional OPC-VG7-UPAC user programmable application card (UPAC).

2. Application to a Power Supply System

2.1 Power backup system with flywheel

Fuji Electric has delivered an inverter that has specifications suitable for use in a power backup system with a flywheel. This power backup system is configured as shown in Fig. 1 and has the following features:

(1) The speed of a flywheel whose inertia is more than 100 times greater than that of the motor is controlled to operate stably at high speed. Motor efficiency during standby is maximized in order to reduce power consumption.

(2) When a power failure is detected, the system switches to automatic voltage regulator (AVR) control, and commercial power is supplied to suppress excessive voltage drops even in the case of a power failure at 150 % load.

Use of this system together with an uninterruptible power supply (UPS) has the advantage of enabling the system to be configured without the use of lead batteries, thereby eliminating the necessity for the processing of specific hazardous wastes. Moreover, the cost of using a UPS is less expensive than batteries when capacity is being enlarged. For these reasons, an increase in demand for these types of systems is anticipated.

Figure 2 shows the backup response after a power failure in the case of 20 kW and a 150 % load. Figure 3 shows the response of load torque fluctuation (100 %

Fig.1 Block diagram of power backup system with flywheel

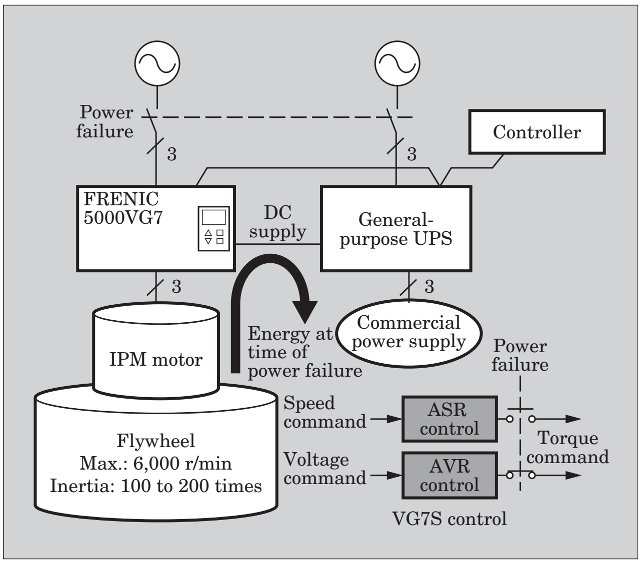


Fig.2 Response of power backup after power failure (20 kW, 150 % load)

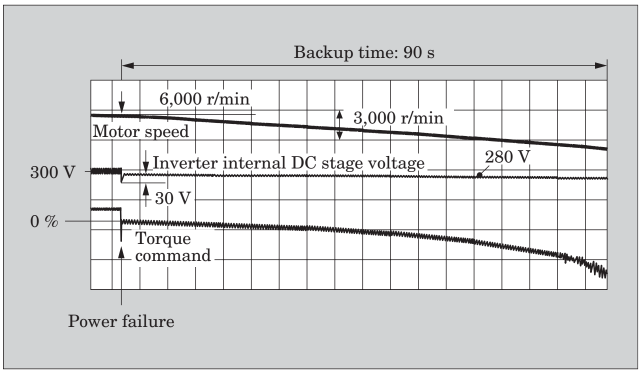


Fig.3 Response of load torque fluctuation during power failure and behavior at power restoration (20 kW, 100 % load)

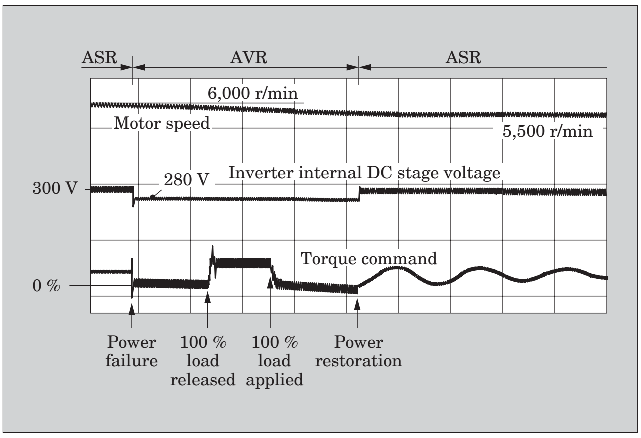
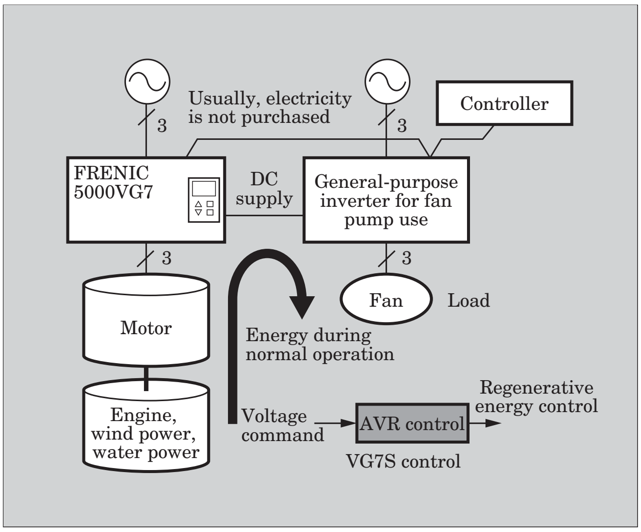


Fig.4 Machine energy regeneration system



load) during backup operation after a power failure and the behavior at power restoration. After power is restored and speed has been selected, the torque fluctuates due to the transition involved in bringing a large inertial body to a constant speed

2.2 Machine energy regeneration system

Figure 4 shows an example application to a system that effectively uses the machine energy.

This system converts surplus kinetic energy such as engine power, wind power or water power into electrical energy and supplies it to a fan or pump. Features of this system are as follows:

(1) Voltage is controlled so that energy is continuously regenerated via the motor.

(2) Controller is monitored to ensure that load does not exceed kinetic energy × total efficiency (machine, motor, inverter efficiency), in order to avoid having to purchase electric power for the system.

Fig.5 Block diagram of gearbox test equipment

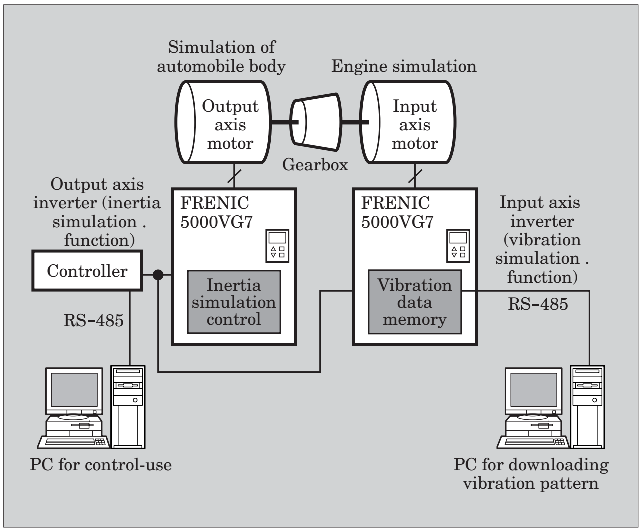
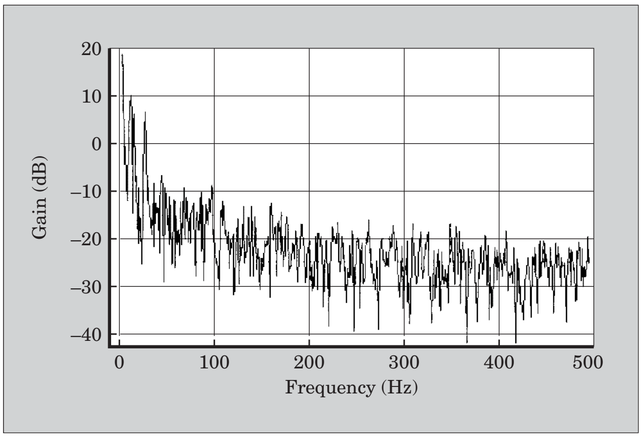


Fig.6 Frequency spectrum of engine driving



3. Application to Gearbox Test Equipment

3.1 Overview of test equipment

This system uses an electric motor to simulate the inertia of the automobile body and engine behavior. System features are as follows:

(1) Complex vibration patterns generated by the engine can be reproduced by means of a vibration simulation function. This enables testing in an environment that closely resembles actual conditions.

(2) Motor inertia can be changed electrically by means of an inertia simulation function. Compared to the conventional fixed-inertia flywheel (mechanical inertia) mechanism, this system allows for a greater variety of tests to be performed and requires less time for the acceleration and deceleration processes.

Figure 5 shows a block diagram of the gearbox test equipment that Fuji Electric recently delivered.

Fig.7 Vibration simulation results

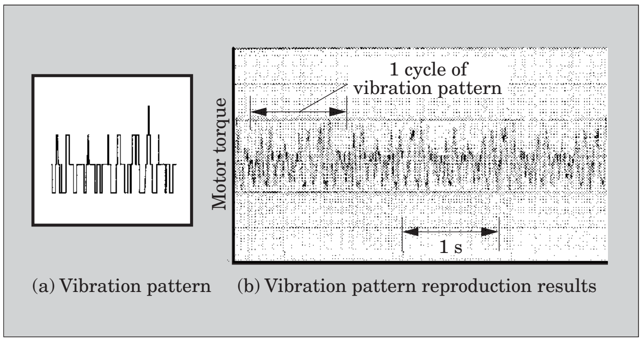


Fig.8 Block diagram of inertia simulation control

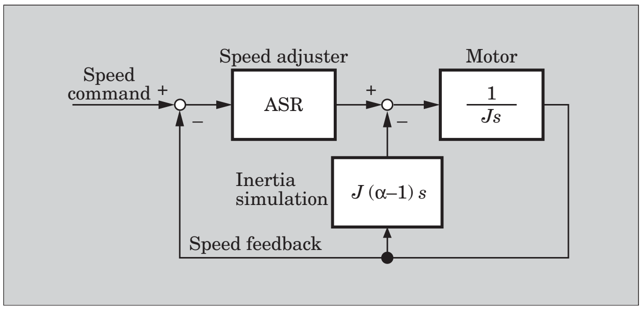
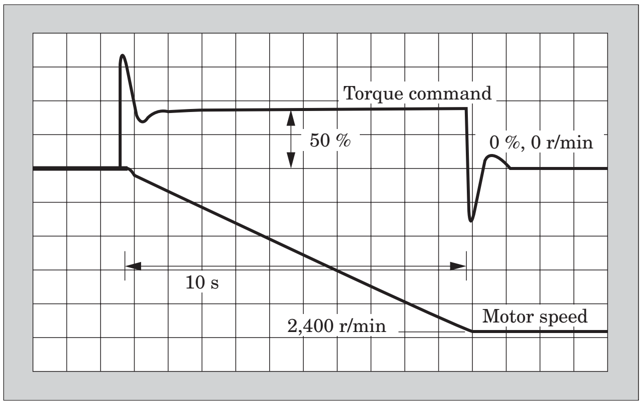


Fig.9 Inertia simulation results (**α** = 2)



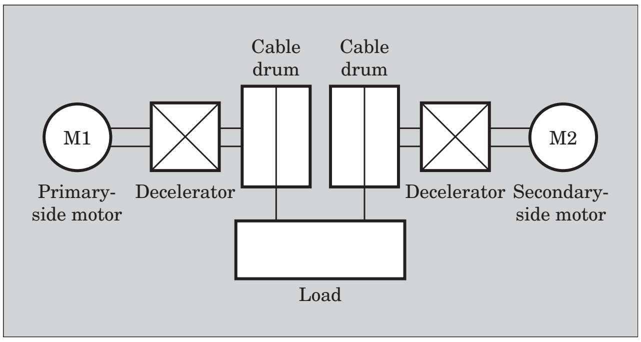
In the system, the output axis motor simulates the automobile body inertia and the input axis motor simulates the engine.

3.2 Vibration simulation

Figure 6 shows the fast Fourier transform (FFT) results of data measured from an actual engine. The simulated frequency band had a maximum frequency of 500 Hz. The vibration pattern is prepared from this data.

Figure 7 shows the results of vibration simulation based on the downloaded data of the vibration pattern of the frequency spectrum of Fig. 6. In the figure, 7(a) is the downloaded vibration pattern for 1 second (engine measurement data), and 7(b) is the result of repeatedly reproducing that pattern.

Fig.10 Example configuration of crane hoisting mechanism



3.3 Inertia simulation

Figure 8 shows a block diagram of the control system for inertia simulation.

In an inertia simulation, the speed response of a motor is made to correspond directly to the inertia to be simulated. The time-rate-of-change of the motor speed feedback is multiplied by J, the motor + mechanical inertia, and by a coefficient (α–1) and the thus computed torque is added to (subtracted from) the output of the speed adjuster (ASR) to express the value of the simulated inertia. The setting operation is performed as follows:

○ $\alpha = 1$: motor + mechanical inertia only
○ $\alpha < 1$: simulates an inertia less than the value of motor + mechanical inertia
○ $\alpha > 1$: simulates an inertia greater than the value of motor + mechanical inertia

Figure 9 shows the acceleration results in the case where inertia ratio $\alpha = 2$. For 100 % torque and acceleration to 2,400 r/min, the acceleration required 5 s when $\alpha = 1$, but nearly twice as long (10 s) was required in a simulation of twice the inertia.

4. Application to a Crane Mechanism

4.1 Synchronized position control

Fuji Electric has delivered an inverter for use in a crane hoisting mechanism. This system is a vertical transport system that consists of two hoisting mechanisms. Its features are as follows:

(1) In addition to the pulse train control of the two motors, in order to compensate for position shifting due to stretching of the hoist rope, the mechanical part of each hoisting mechanism is provided with a sensor and the positional relationship of the two hoisting mechanisms is automatically corrected in real time.

(2) The amount of position correction is stored even when power is off so that the synchronous positions can be kept.

Figure 10 shows an example configuration of the crane hoisting mechanism.

Fig.11 Block diagram of trace back system

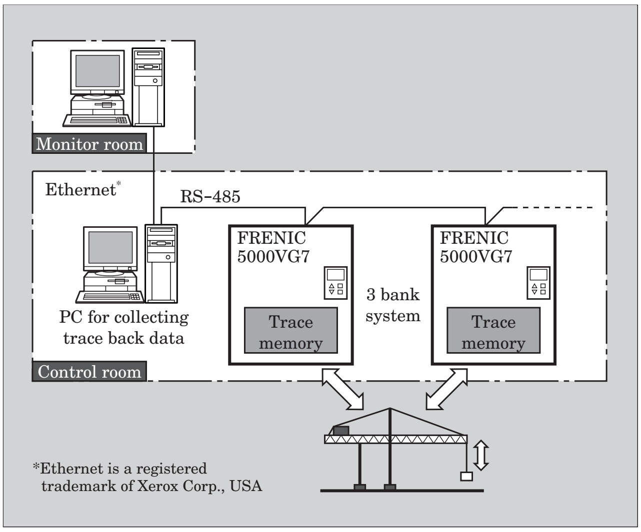


Fig.12 Example configuration of Ward-Leonard system

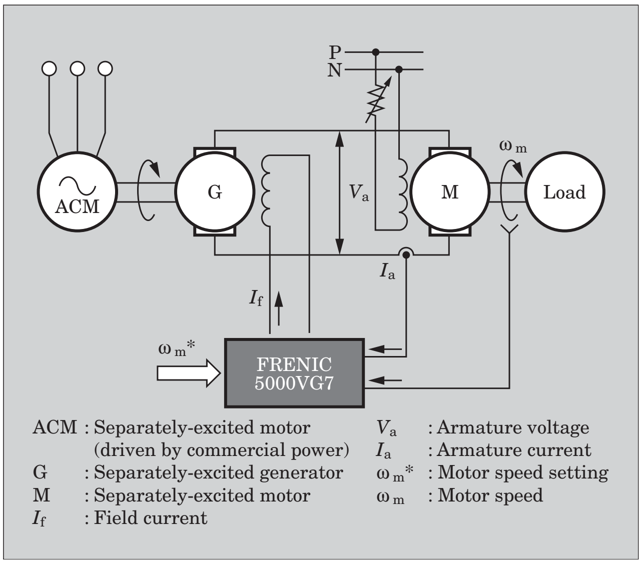
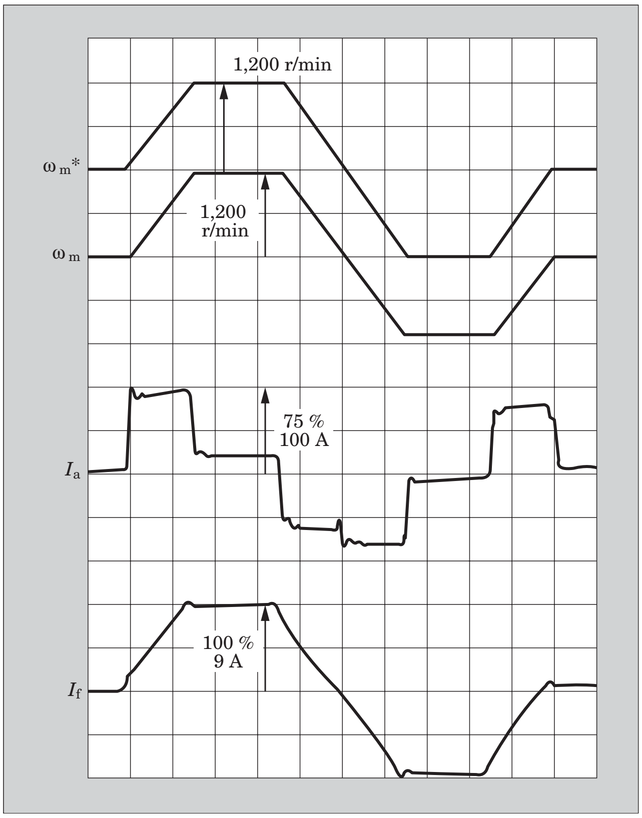


Table 1 Trace back conditions

Item	Unit	Min.	Max. value
Number of banks	—	1	3
Sampling time	ms	1	10
Total measurement time	ms	500	1,500
Measurement time before trigger	ms	0	1,500

Fig.13 Operating data



4.2 Trace back system

Fuji Electric has delivered a trace back system that monitors the operating status of a harbor crane and supports data analysis in the case of an abnormality. This system is configured from VG7S inverters, a UPS and a PC. System features are as follows:

(1) The system is comprised of a monitor room and a control room, such that the operating status of several VG7S inverters in the control room can be monitored all at once from a PC located in the monitor room.

(2) The occurrence of an abnormality triggers various types of data to be saved automatically. It is possible to connect the PC only in cases when an abnormality occurs.

Figure 11 shows an outline of the trace back system.

From a list of 20 items including speed setting, speed detection and motor output, data trace back is possible for a maximum of 8 selected items. Moreover, the trace back conditions of Table 1 may set to enable trace back to be realized according to various intended purposes.

5. Application to DC Machine Driving

The use of a Ward-Leonard system to control the voltage of a DC motor has long been established. Figure 12 shows an example system configuration. Here, separately-excited motor (M) is electrically connected to separately-excited generator (G). VG7S adjusts the field current (I_f) of G, which is direct-coupled to induction motor (ACM), to manipulate armature current (I_a) and control the motor torque. Additionally, speed control is performed by means of motor speed (ω_m) feedback. This system was delivered to replace an older system.

Figure 13 shows the operation of an actual assembly for acceleration and deceleration up to the rated speed. I_a and I_f increase according to the motor speed setting (ω_m*). I_f is controlled to generated armature voltage (Va) in accordance with ω_m, and I_a is controlled according to the acceleration and deceleration pattern of the motor.

6. Conclusion

An overview of applied examples of the control technology of the high-performance vector-control inverter FRENIC5000VG7S has been presented above.

Hereafter, Fuji Electric will continue to leverage the flexible technology of digital control systems, and in addition to applications for driving induction machines, synchronous machines and DC machines, will strive to development applications that utilize the UPAC, to realize various types of functions and performance, and to develop inverters that meet user requirements.

Lastly, the authors wish to express their sincere gratitude to the users who graciously accommodated our requests during the write-up of system examples for this paper.