HIGH PERFORMANCE INVERTER DRIVING SYSTEM FRENIC5000VG3 FOR INDUSTRIAL USE

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1. INTRODUCTION

Recently, the capacity of the power transistor voltage type inverter, which occupies much of all variable speed driving systems, has been extended up to 1,000 kVA by means of the higher performance and capacity of the power transistor that makes up its main circuit. Digitalization and LSI of the control circuit is also advancing. The circuit has become smaller and operability has been improved too. On the other hand, pumps and other energy-saving driving inverters have already reached the market and their annual production is increasing. Automation and FA of the machining industry, transportation facilities, etc. are increasing, in addition to these energy-saving applications, and the demand for high performance variable speed driving systems that can handle systems for these applications is rising.

In particular, conventionally, the movement toward inverter drive that allows improved maintainability and labor-saving by using an induction motor is becoming stronger in processes that can be only dealt with by DC motor control.

To meet these market needs, Fuji Electric markets the new series FRENIC5000VG3, which is a full model change of the high performance vector control inverter FRENIC 5000VG combined with a special induction motor. This series is outlined below.

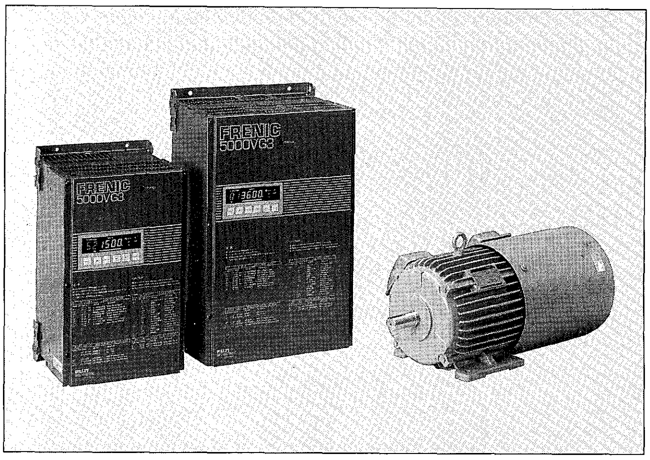
2. FEATURES

The FRENIC5000VG3 is shown in **Fig. 1**. Compared to the old FRENIC5000VG series, this new series was planned to advance digitalization and increase the functions and performance in the area of control. It was especially developed so that it can be applied to both single unit drive and to multi-motor drive systems demanded by the market. Its features are described below.

2.1 Quick speed response

The speed control frequency response was increased to 50 Hz or more by using a 32-bit DSP (Digital Signal Processor) at the control circuit to increase the speed control loop calculation processing speed. This not only allows speed control, but also fast position control possible by adding an external position control loop.

Fig. 1 Drive unit and special motor of FRENIC5000VG3



2.2 High speed control precision

The high speed control precision (±0.01%) demanded by paper manufacturing lines, film manufacturing lines, etc. has been realized by raising the speed control operation resolution and improving precision.

2.3 Wide speed control range

Stable operation at the low speed range has been made possible by widening the speed control range up to a maximum 1:1,000 by using Fuji Electric's original speed sensing system with high pulse count pulse encoder as the speed sensor.

2.4 High torque control precision

Overall torque precision has been improved ±5% by motor temperature correction, motor loss compensation, etc. and application to pay-off reel, winder, and other tension control that demand high torque precision has become possible.

2.5 Abundant control functions

Fifteen control functions are provided as standard so that the series can be used in all variable speed control applications. These functions include vector control inherent torque limit, torque bias, droop control, and similar functions, besides S-curve soft start/stop, multi-step speed reference, and UP-DOWN speed reference.

2.6 Easy-to-use human communication interface

In addition to auto speed regulator gain, reset time, and other parameters setting and display, motor speed and torque, motor temperature, current value, operation status and inverter input/output interface status, etc. can be displayed at a keypad panel at the front of the drive unit for improved operability.

2.7 Complete transmission function

Optional T-link transmission with a Fuji Electric programmable controller (PC) (MICREX-F) and RS-232C transmission with a personal computer can be built into the system for line drive control and monitoring, and other system control.

2.8 Complete RAS functions

The operation status when a fault occurs can be retrieved with keypad panel on the front of the drive unit. Since the speed, current, etc. when a fault occurs can be traced back on a personal computer by using the transmission function previously mentioned, fault diagnosis can be performed quickly.

2.9 Miniaturization

The drive unit volume could be made about 50% (3.7-45kW) more compact than the old series. The cooling section and transistor drive section have been miniaturized by using a low-loss, high current gain power transistor at the main circuit of the inverter. And PC board size also have been miniaturized by using LSIs and SMT (Surface Mount Technology).

3. SPECIFICATIONS

The specifications are shown in **Table 1**. The basic circuit configuration is shown in **Fig. 2**. Typical new specifications are described below.

3.1 Wide capacity range and improved control performance

200V series: 0.75-90 kW, 400V series: 3.7-800 kW capacity series have been completed and speed control response, control precision, and torque control precision have been improved. Most variable speed systems, from small to large, can be built with this series.

3.2 Stall torque

Overload capacity is the same 150% as in the past, but the capacity during the stall operation necessary for loading equipment, winder control, etc. has been increased to 80% continuous, 150% for 30 seconds. This is about double that of a DC motor.

3.3 Control functions

Five digital inputs (X1-X5), which allow selection of acceleration/deceleration time changeover, multi-step speed reference, and UP-DOWN speed reference, besides operation command, pre-excitation command, etc., are provided as operation functions. Two analog input signals (AI1, AI2) are also provided. These signals can be used for the speed compensation setting necessary at loop control and other torque limiting demanded by torque control, and other input. As an operation monitor, four digital outputs (relay contact: 1, open collector: 3) used in speed arrival, optional torque detection overload prediction and one analog output (A0) capable of outputting the speed reference and actual speed for line operation ratio control etc. are provided. Mechanically tied control can be per-

Table 1 Standard specifications of FRENIC5000VG3

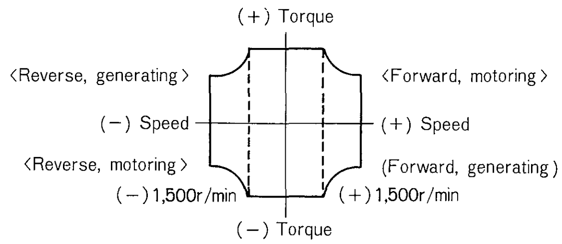
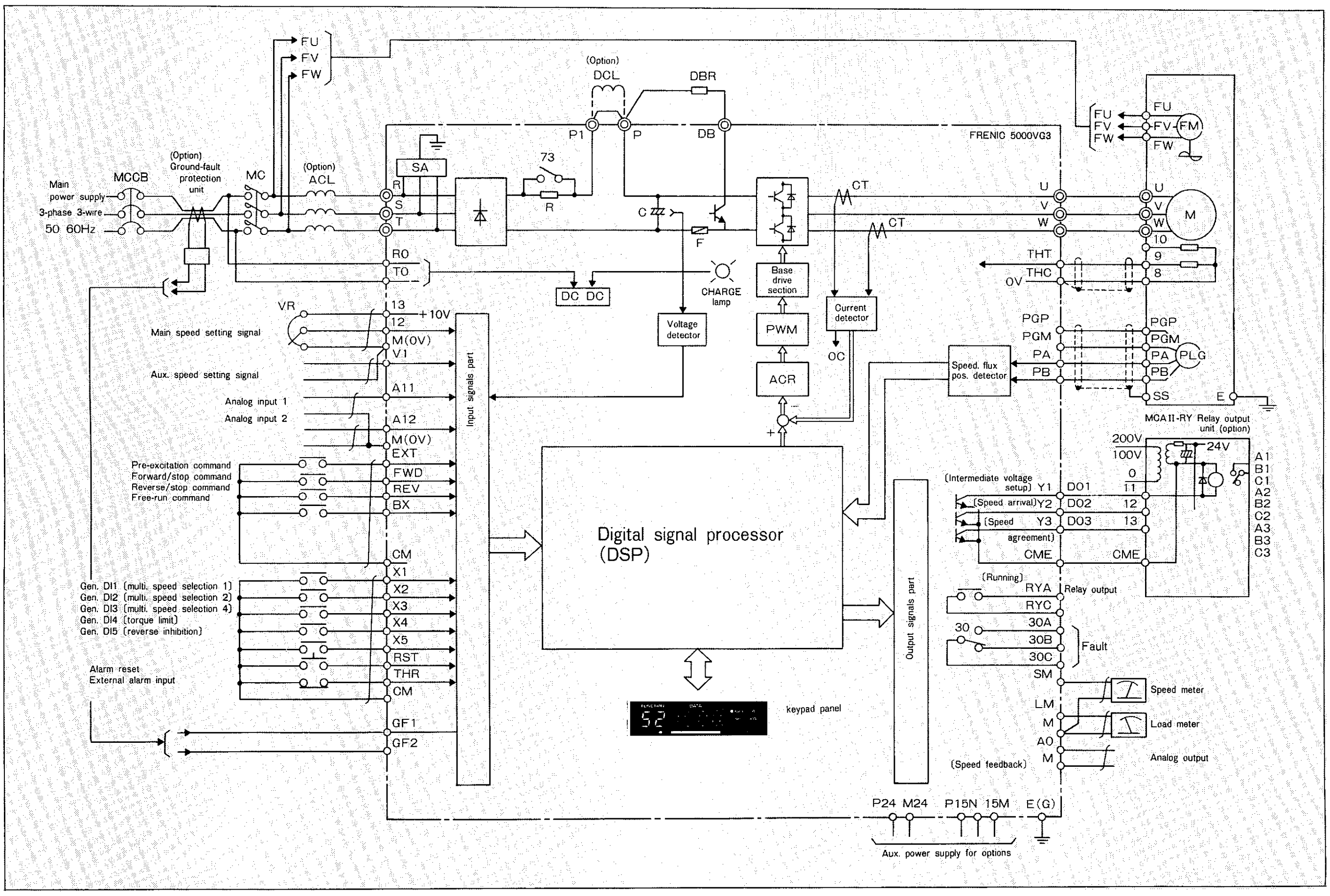
Main-circuit system		Transistor type sine-wave PWM inverter
Control system		Vector controlled, ASR control with ACR minor control (ACR: current control, ASR: speed control)
Speed control precision	Analog setting	±0.2% of max. speed (25±10°C)
	Digital setting	±0.01% of max. speed (−10–+50°C)
Speed setting resolution		0.005% of max. speed
Speed control response		Response frequency 50Hz (−3dB)
Range of torque control		1 : 50
Torque control precision		±5% (total precision)
Speed-torque characteristics		 4-quadrant operation Max. torque: 150%, 1 min Stalled torque: 80%, cont.
Acc./dec. characteristics		Torque-limiting acceleration/deceleration, linear acc/dec (0.10-1,200 s), curved (S-curve) acc./dec.
Braking method		Dynamic braking resistor method: 150%, duty cycle 5% ED, provided with separate brake resistor(s), and separate brake unit(s) in addition for 55kW and above.

Fig. 2 Basic circuit configuration of FRENIC5000VG3

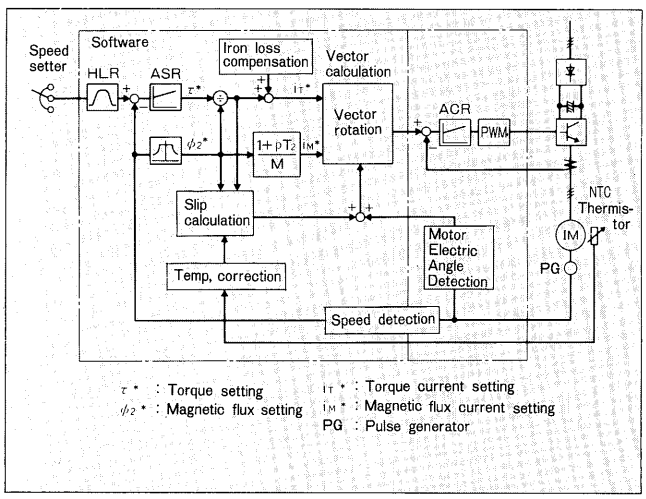


formed with the standard functions by using this analog output signal as torque control. The basic control block diagram is shown in **Fig. 3**. The speed reference and speed control section and vector calculation section are programmed and high speed calculation processing is performed by DSP. To improve the torque characteristic, the motor temperature is sensed and rotor resistance temperature correction is performed, and also motor iron-loss compensation is performed. The current control section hardware is configured to suppress the torque ripple and realize high speed response and to change pulse width modulation (PWM) switching frequencies up to the high range.

4. OPERATION CHARACTERISTICS

The typical operation characteristics are described below. **Figure 4** shows the $0 \rightarrow +1{,}500$ r/min $\rightarrow -1{,}500$ r/min acceleration and deceleration characteristics. The actual speed tracks the speed reference value without any delay and smooth acceleration and deceleration characteristics with little overshoot and undershoot are obtained. Since an induction motor generates a flux delay at starting, the transient torque at starting may be insufficient and a starting delay may be generated. A new flux delay compensation function has been added to this new series to improve the starting characteristics as shown in **Fig. 5**.

Fig. 3 Control block diagram



Slipping at starting at crane facility hoist, etc. can be prevented by these characteristics.

Figure 6 shows the speed control characteristics at the low speed range (1% or less). The actual speed does not have offset relative to the speed reference even at 1% or less and the characteristics are linear up to 1/1,000 speed. **Figure 7** shows the step response at this low speed. It is the motor speed response characteristic when the speed reference was changed in steps from 10 r/min to 11 r/min.

Fig. 4 Characteristics of acceleration and deceleration

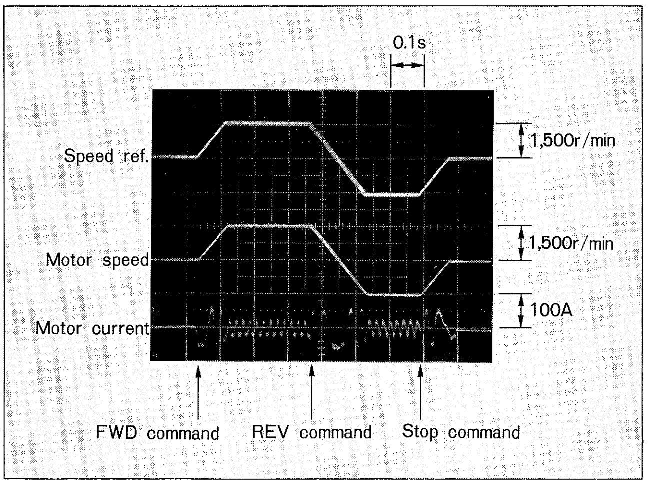


Fig. 5 Starting characteristics (0 → 1,500 r/min)

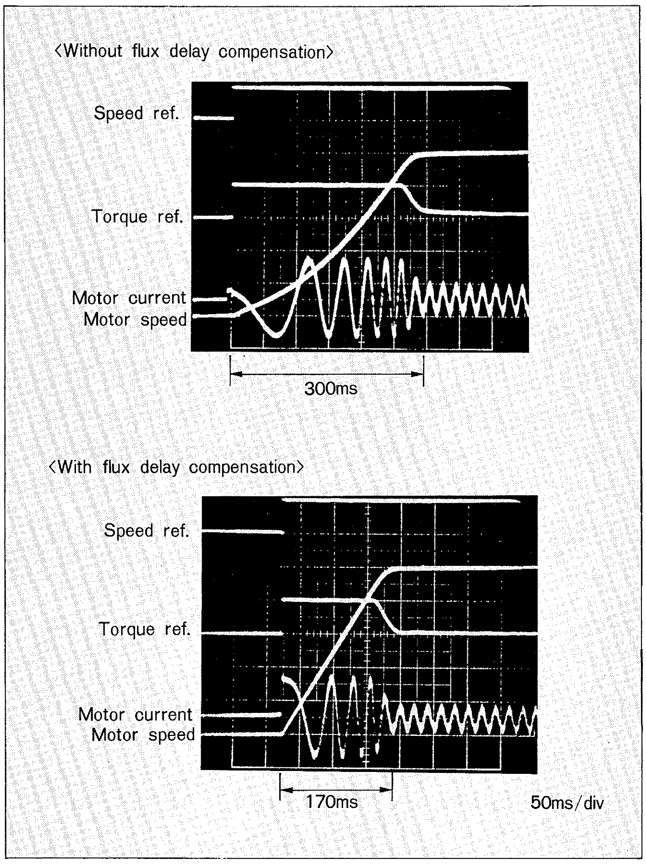


Fig. 6 Speed control characteristics at low speed range

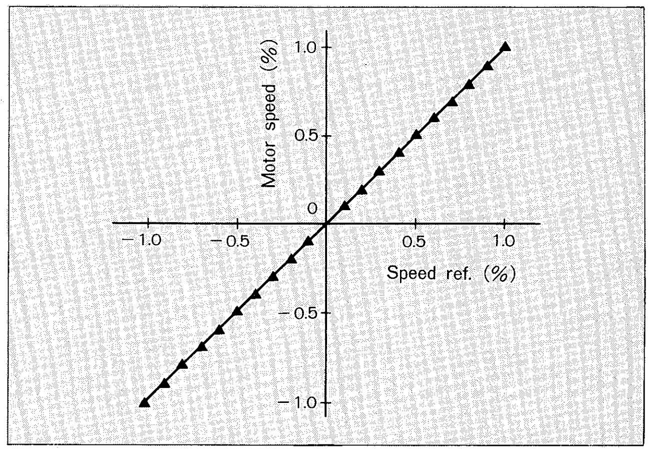
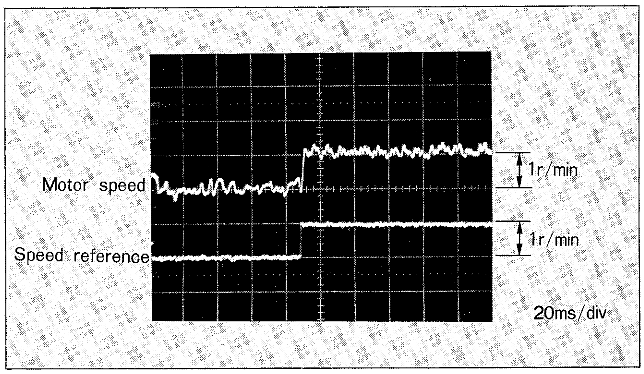


Fig. 7 Step response at low speed



The speed response and resolution are high and even 1 r/min step changes are tracked without delay.

The torque characteristic is introduced next. Induction motor control contains an iron loss and a rotor resistance temperature change, which have a large effect on the flux component, as elements that worsen the torque control precision. For this series, the torque characteristic was improved by compensating both these elements. **Figure 8** shows the torque reference - actual torque characteristics with and without iron-loss compensation. Without iron-loss compensation, the actual torque is small in the motoring mode and large in the generating mode. With iron-loss compensation, a torque characteristic close to the theoretical value was obtained in both the motoring and generating modes. **Figure 9** shows the torque characteristics when the motor temperature was changed near the rated torque of a 7.5W, 1,500 r/min motor. An almost flat torque characteristic is obtained by sensing the motor internal temperature with a thermistor and performing rotor resistance temperature correction.

Next, an example of operation using the standard functions of this seires is described.

Figure 10 shows the operation characteristic at a momentary voltage drop. Figure (a) is the characteristics for a momentary voltage drop of within 15 ms. For a short (within 15 ms) power drop, operation can be continued without any change of motor current and speed. Figure (b) is the characteristics for a voltage drop of approximately 0.2 second. Immediately after the voltage drop, the motor current is cut off and the motor speed drops according to the load torque. After the power recovers and the smoothing capacitor provided at the DC intermediate circuit has change up to the prescribed voltage, the inverter re-energizes the motor. At this time, the control circuit performs control so that the soft start/stop output always coincides with the motor speed. Therefore, after the voltage recovers,

Fig. 8 Torque control characteristics

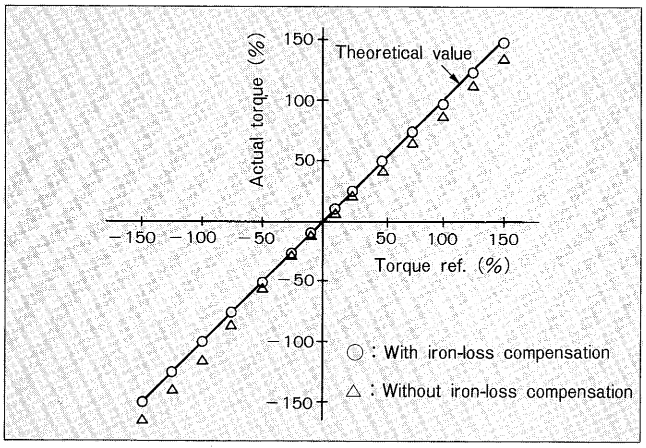
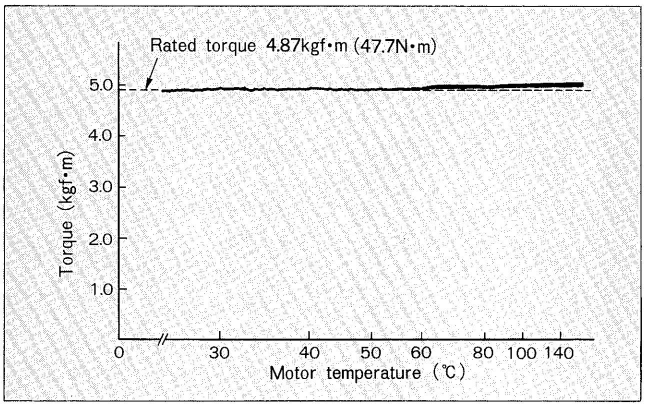


Fig. 9 Torque-motor temperature characteristics (motor 7.5 kW, 1,500 r/min)



the motor speed rises smoothly to its speed before the voltage drop.

5. SYSTEM CORRESPONDENCE

The FRENIC5000VG3 is provided with complete options so that a system can be easily built for line control demanding cascade control, synchronizing control, tension control, etc. System correspondence using these options is introduced here. **Figure 11** shows the basic system configuration. **Table 2** shows the control options. Two digital interface options, including a T-link interface card for transmission with a PC (MICREX-F), can be installed in the drive unit. An adder, F/V converter, and other input/output options can also be installed.

5.1 Serial transmission with MICREX-F

For line control, systems that perform cascade control, tension control and other using PC are increasing. The reasons for this are that market needs in the control field have become more advanced and PC processing speed has increased and an inexpensive system can be built. With the FRENIC5000VG3, T-link transmission with the Fuji Electric PC MICREX-F is made as a standard system. The

Fig. 10 Automatic speed pick-up after momentary voltage drop

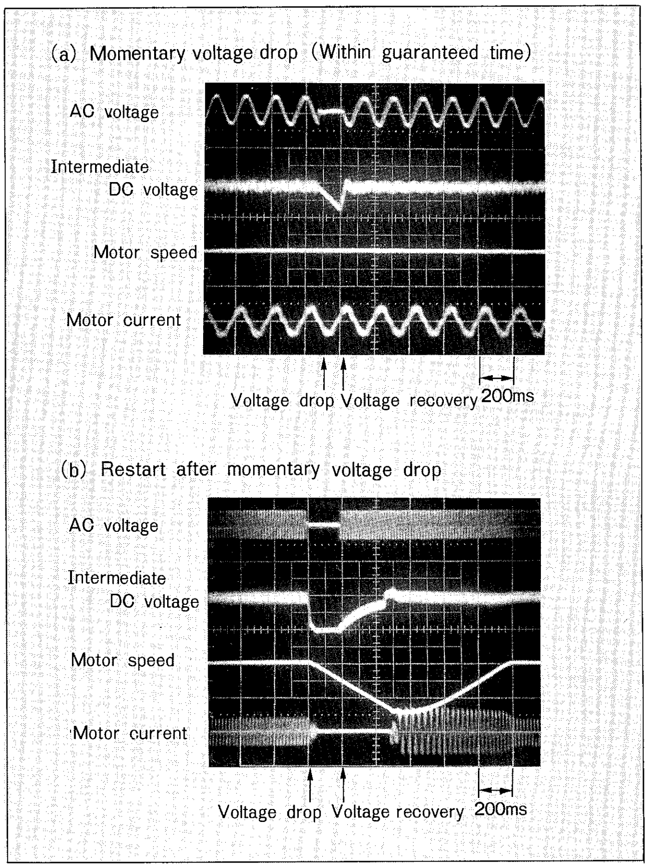
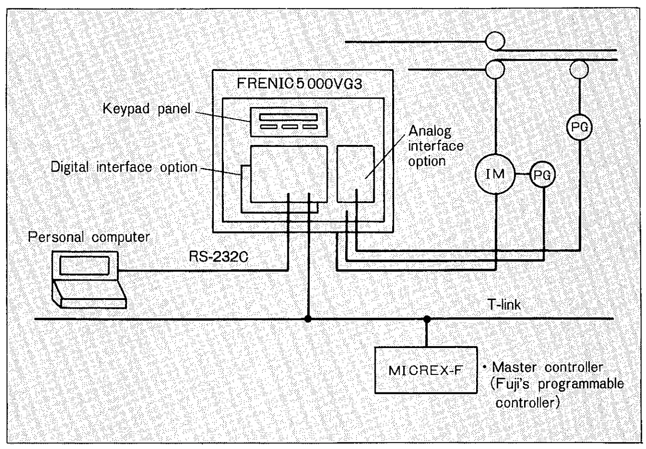


Fig. 11 FRENIC5000VG3 system configuration



transmission contents between PC and drive unit are shown in **Table 3**. With T-link transmission, all the data needed for inverter operation can be exchanged and all the operation status data that can be set and displayed with the drive unit keypad panel can be read and changed at the PC side. Moreover, since six inverters can be connected in one T-link, a MICREX-F with four T-links can control up to 24 inverters. Therefore, this system can amply handle medium size facilities for variable speed drive of about 20 motors. An example of application to a film manufacturing line using

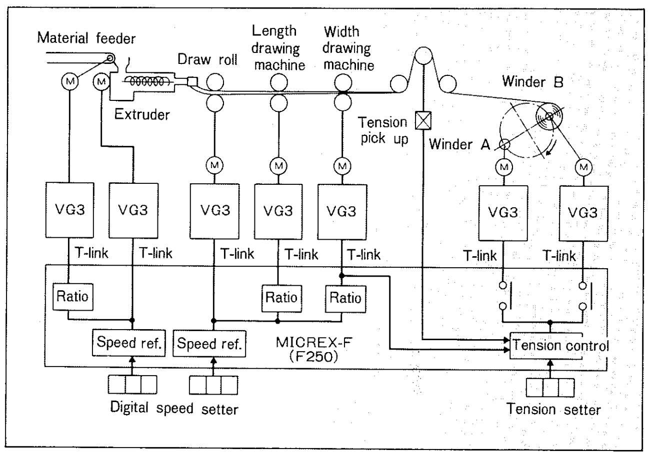
Table 2 Control options

Name	DI interface	AO interface	T-link interface
Type	OPCII-VG3-DI	OPCII-VG3-AO	OPCII-VG3-T2
Function and use	Converts 16-bit binary signals or 4-digit BCD signals into speed setting signals. (1) 16-bit binary signals 20,000/max. forward speed, Reverse is expressed by twos complement. (2) BCD signals −7999−+7999	Outputs analog signals of inverter internal data (actual speed, speed setting, torque setting) to outside. 0−±10V DC, 2 channels.	Connects Fuji programmable controller MICREX-F with T link. RS-232C interface is also available. Using T link and RS-232C, writing and setting of speed and parameters are made possible. The option stores back data for fault trace.
Name	Adder-subtracter	I/V, V/I converter	Comparator
Type	OPCII-VG3-AD, MCAII-VG3-AD	OPCII-VG3-IV, MCAII-VG3-IV	OPCII-VG3-CP, MCAII-VG3-CP
Function and use	• Addition and subtraction of 2 inputs (2 circuits) • Output limiting (1 circuit) • I/O: 0−±10V DC.	Applies to the use of instrument signals as speed setting signals. • Conversion of 0−+10V DC and 4−20mA DC • I/V conversion: 1 circuit V/I conversion: 1 circuit • Input-output not isolated.	Used for level detection of speed and torque • Comparator 2 circuits (contact output) • Input: 0−±10V DC • Output: Contact signal (1c), contact capacity 250V AC, 0.3A, $\cos\phi = 0.3$.
Name	Isolation converter	Dancer controller	F/V converter
Type	OPCII-VG3-IA, MCA II-VG3-IA	MCAII-PU	OPCII-VG3-FV, MCAII-VG3-FV
Function and use	Used to isolate analog input signals when wiring distance between the inverter and other devices or the speed setting is long. • I/O: 0−±10V DC.	A PID controller for dancer control. • Input signals Synchronous oscillator: 80−121 V AC, 180−253V AC, or DC voltage signal 0−±10V DC. • Output signal: 0−±10V DC	When detecting line speed with a pulse encoder, converts frequency signals into voltage signals. • Input signal Frequency: 5−40kHz Signal mode: Voltage pulse input 12−15V or complementary line driver 5−15V • Output signal: 0−+10V DC 0−±10V DC.

Table 3 Transmission function with MICREX-F

Type	T-link, 500kbps (10ms refreshing), 1 : N
Function	(1) Setting of 4 kinds of parameters (example) Commands (FWD, REV, BX, . . .) Speed reference ASR P·I (2) Readout of 4 kinds of parameters (example) Torque reference Motor current (3) Readout of actual speed and inverter's mode

Fig. 12 Application to film manufacturing line



this system is shown in **Fig. 12**. Ratio control is performed from extruder to width drawing machine with speed control precision ±0.01%. The winder performs tension control with taper tension.

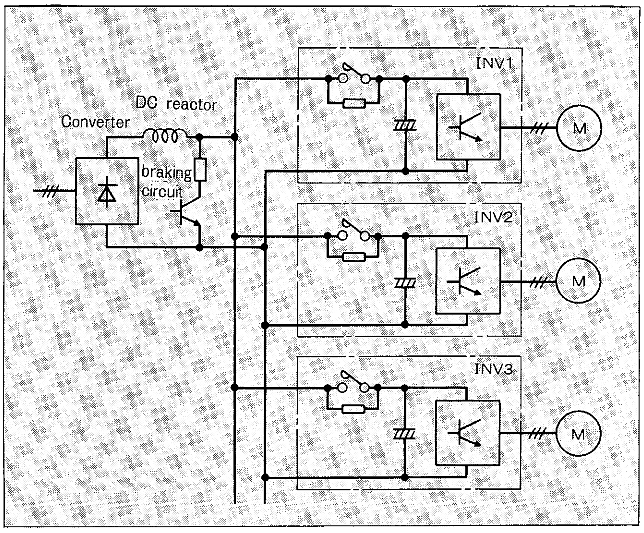
5.2 DC common-bus system

Processing lines and other multiple motor operation control contain one or two motors in one line that require continuous generating operation such as an unwinder. The DC common-bus system is a method which reduces the power supply capacity by using a common DC power supply section for inverter of these motors and motors which are operated in the motoring mode common and supplying generating energy directly to the other driving motors. **Figure 13** shows an example of the FRENIC 5000VG3 DC common bus method. DC power is supplied by a diode rectifier and a low capacity resistor braking circuit that absorbs the energy of inertia at line stopping and other deceleration is provided at the common DC intermediate circuit.

6. CONCLUSION

An outline of the newly developed variable speed driving system FRENIC5000VG3 for industrial use was introduced above. The control functions were substantially improved and the functions were increased and size and weight were reduced. This series is expected to be applied to a wider field as the successor to the FRENIC5000VG. System construction for automation, FA, etc. is also easy and since the RAS functions and other reliability

Fig. 13 Example of DC common-bus method



have also been improved, we are confident that it can amply meet the needs of this field.

For the 200V series 0.75 to 22 kW models, an IGBT (Insulated Gate Bipolar Transistor) is used as the power elements and the FRENIC5000VG3N designed for to minimize acoustic noise has been serialized.

Backed up by power electronics, microelectronics, control technology, and other new technology, efforts will be made further to develop inverters which meet market needs.