Fuji Medium-voltage IGBT Inverters

FRENIC4600FM5e

AC Adjustable Speed Drive

Fuji Electric Systems Co., Ltd.
Environment-friendly inverters.

Fuji medium-voltage IGBT inverter FRENIC4600FM5e is used for direct variable-speed control of medium-voltage motors, and greatly raises the efficiency and power factor, stabilizes motor operation and conserves energy.

Compact design for space saving
- The industry’s smallest-class inverter achieved by significant panel size reduction

Ideal inverter for power sources and motors
- The multi-phase diode rectifier system reduces harmonics on the power source side.
- Due to the use of Fuji Electric’s unique multi-level PWM control system, the switching surge is reduced and existing motors (standard ones) can be operated.

High-efficiency and high-power factor
- The use of a multi-phase diode, full-wave rectifier provides a high-power factor (95% or more) on the power source.
- The elimination of output transformers for operation has improved total efficiency (approx. 97%).
- Fuji Electric’s original multi-level PWM control has reduced the IGBT switching loss.

High-reliability
- Higher equipment reliability is achieved by reducing the number of inverter cells by using a single-phase, 3-level inverter, etc.
- Stable operation is maintained despite load fluctuations, by the simple sensor-less vector control function.
- The control device has a 32-bit MPU for quick response and high-accuracy.

Contributes to energy saving
- A substantial energy saving is achieved by variable-speed control of a square-law reduced torque load such as a fan or pump.

Easy maintenance
- The inverter is air-cooled, requiring no cooling water.
- Start/stop operation, parameter setting, fault display and data monitoring are performed from the touch panel with simple loader functions.
- Simple, built-in auto-tuning functions facilitate testing and adjustment.
- Fault diagnoses are easily performed.
- A dry-type input transformer is adopted.
High-reliability and simple-maintenance inverters utilizing the latest power electronics such as 3-level inverter, mounting of special MPU and no need for harmonic filter/power-factor regulating capacitor.

**Cooling fan**
- Air-cooled inverters make maintenance easy.

**Inverter cell**
- The number of inverter cells has been substantially reduced by adopting a single-phase, 3-level inverter design.
- Each inverter cell alone can be replaced easily, because the controller, diodes, IGBT elements and DC intermediate capacitor are combined into an integral body.

**Master control PC board**
- Mounting of a 32-bit MPU, and a special MPU in the voltage and current detection system offers a quick response and high accuracy.
- Incorporation of a simple sensor-less vector control function enables inverters to maintain stable operation irrespective of load fluctuation even without a speed sensor.
- Vector control with a speed sensor is available (as an option) for equipment having high speed and torque accuracy requirements.

**Input multiplex-winding transformer**
- Harmonic current on the power source side is low due to a multiplex configuration of the secondary winding.
- An equivalence of 36-phase rectification is effected, so harmonic current satisfies the standard level of IEEE.
- Harmonic filters and power factor improving capacitors are not needed.
- Because a dry-type input transformer is used in the panel, external cabling work between the input transformer and inverter panel is no longer necessary.

When requested, protection covers can be provided inside the inverter panel (as an option). Protection covers will protect from unexpected contact with live metal parts of the main circuit.
Environment-friendly

Clean power input

Substantial reduction of harmonic current on power source side

Due to progress in power electronics, semiconductors have recently been used for industrial electrical equipment and household electrical appliances in order to enhance convenience and ease of operation. However, due to harmonic currents generated from such equipment and appliances, the voltage of the power system is often distorted and many troubles occur in equipment connected to the power system. However, because the use of equipment containing power electronics will increase, measures for suppressing harmonics need to be improved. FRENIC4600FM5e suppresses the harmonics by using a multi-phase diode rectification system (equivalent to 36-phase rectification), thereby substantially reducing the generation of harmonics in comparison with previous models. The harmonic generation level stipulated in IEEE-519 (1992) is satisfied. This inverter is ideal for power sources.

Total inverter efficiency as high as approximate 97% (at full load)

Because an output transformer is unnecessary, inherent losses are eliminated.

Multi-level PWM control minimizes switching loss.

Because the harmonic current on the power source side is reduced, the primary winding of the input transformer has a reduced loss due to the harmonics.

Source power factor as high as 95% or more (at full load)

Due to full-wave rectification with multi-phase diodes, operation is allowed with the source power factor (power factor on power source side) set at a high level.

A phase advancing capacitor and a DC reactor for improving the source power factor are unnecessary.

A smaller power capacity suffices for inverter operation.

Friendly to machines

If a harmonic current component is contained in the inverter output current, a torque ripple occurs on the output shaft of a motor. A torque ripple means a change in rotational speed or a large vibration if the frequency of the torque ripple matches the natural frequency of the mechanical system and torque ripple is large.

In FRENIC4600FM5e, the harmonic component on the output side is extremely small due to the multi-level (max. 17 levels) PWM control and the main component of torque ripple is at around the carrier frequency (several kHz). Therefore, torque ripple hardly affects the machine side.

Friendly to motors

The multi-level PWM control provides an almost sinusoidal output current waveform, thus reducing motor torque ripple.

Because the output current is almost sinusoidal, a motor suffers less loss due to harmonics.

The multi-level (max. 17 levels) PWM control minimizes switching surge and thereby reduces stress on the motor.

There is no need to reduce motor capacity due to inverter drive.

There is no need for special cables, etc. due to inverter drive.

This inverter is applicable not only to a square-law reduced torque load, but also to a constant torque load such as an extruder.

For driving a large-capacity motor in a system that has a small power capacity, voltage fluctuation, etc., due to the starting current of a motor will cause problems. However, because the starting current can be suppressed by the soft start of this inverter, operation can be performed.

Note

Surge voltage and multi-level output

The output voltage waveform of a PWM inverter is a DC-chopping voltage (called “pulse voltage” or “surge voltage”) whose amplitude is determined by voltage Ed of the DC intermediate circuit. When this surge voltage of inverter output is applied to a motor through a cable, the voltage is reflected repeatedly between the motor terminal and inverter terminal. A sharp overvoltage higher than the inverter output voltage is thus generated at the motor terminal, which may cause electric breakdown of the winding. The maximum level of the overvoltage class close to twice the DC intermediate circuit voltage Ed of the inverter. Fuji Electric’s medium-voltage inverter suppresses the DC intermediate circuit voltage level so as to realize an output voltage waveform at 9 levels in the 3kV class and at 17 levels in the 6kV class. As a result, the overvoltage generated at the motor terminal can be suppressed.

In the 3kV class Fuji Electric’s medium-voltage inverter, the output voltage changes in 3 steps (corresponding to 3 levels) within 1/4 cycle. The voltage value of one step equals the DC intermediate circuit voltage Ed. Therefore, for the same voltage output, a larger number of steps means a smaller voltage value at one step. Thus, Fuji Electric’s inverter can also reduce the surge voltage appearing at the motor terminal and thereby moderate the stress applied to the motor.
System voltage
Inverter voltage

Synchronizing in progress
Synchronization completed

Breaker lapping in progress

Main circuit configuration

Fig. 1 Main circuit configuration of 3.3kV type

Fig. 2 Internal configuration of inverter cell

Fig. 3 3-level voltage output

Fig. 4 2-level voltage output

Ed: DC intermediate circuit voltage

Principle of operation
FRENIC4600FM5e consists of an input transformer and 6 inverter cells in case of the 3kV type as shown in Fig. 1 (12 inverter cells in case of the 6kV type). One inverter cell consists of a single-phase, 3-level inverter and can receive an output voltage of 953V. As shown in Fig. 1, the 3kV type obtains a phase voltage of about 1,900V by connecting 2 inverter cells vertically and a star connection of the vertical cell pairs can generate a line voltage of about 3,300V. Use of the single-phase, 3-level inverter doubles the output voltage obtainable from one cell when compared with a single-phase, 2-level inverter. Therefore, an output voltage of 3.3 or 6.6kV can be obtained by using a smaller number of inverter cells. (See Figs. 3 and 4.)

Commercial power supply bypass circuit/restarting function after momentary interruption

Changeover to the starting circuit by commercial power supply can be made by installing a bypass circuit (option) on the inverter output side. In this configuration, motor drive power supply is duplicated, and changeover between commercial power supply and inverter operation is allowed for running a motor at the rated speed. (See Fig. 6.)

Shockless switching between inverter operation and commercial power operation allowed by phase control according to system voltage. (See Fig. 6.)

(Synchronizing/parallel off function: option)
An electric reactor must be installed on the output side of the inverter to enable this function.

In the event of a voltage drop due to a momentary power interruption, the operation processing pattern can be selected according to the application.

1. Selection of major fault at voltage drop due to momentary power interruption
The inverter is stopped in the major fault status and the motor is set in the free run status.

2. Selection of restart under free run (option)
Inverter operation is stopped and the motor is set in the free run status. Upon power recovery, the motor under acceleration in free run or under stop is automatically accelerated again through a speed search function.

3. Selection of continuing operation at voltage drop due to momentary power interruption (option)
Inverter operation is continued without setting the motor in the free run status even when a voltage drop occurs. As soon as line voltage is recovered, the motor is accelerated again back to the operating speed.

Commercial power supply bypass circuit/restarting function after momentary interruption

Notes:
1. A voltage drop due to a momentary power interruption will be detected at 80% or less of the rated voltage.
2. Operation can be continued within 300ms at a voltage drop due to a momentary power interruption (option).
**Data setting and monitoring**

**Operation and monitoring simplified by the touch panel equipped with LCD**

- **LED monitor**
  - Under load running: Displays the number of revolutions.
  - At tripping: Flashing ‘Err’ is displayed.

- **LCD monitor**
  - Displays various information including operation data, set data and fault data.

- **Run key**
  - Used for changing data No. and values of data setting.

- **Program key**
  - Used for moving to the monitor screen.

- **Shift key (digit shift)**
  - Used for shift the position of the cursor from one digit to another in order to change data.

- **Reset key**
  - At tripping: Releases the stop status due to tripping.
  - Under programming: Returns to the previous layer.

**Display description of the touch panel**

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Number of items</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Current, voltage and frequency at present(*)</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Parameter setting items</td>
<td>About 320</td>
</tr>
<tr>
<td>3</td>
<td>D/D (RAM) status display</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>AI/DO status display</td>
<td>About 80</td>
</tr>
<tr>
<td>5</td>
<td>Data indication</td>
<td>About 20</td>
</tr>
<tr>
<td>6</td>
<td>Cause of fault</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>Present time, operation time</td>
<td>2</td>
</tr>
</tbody>
</table>

(*) Displays 7 items on the 2-image screen.

**Other functions**
- **Fault history**
  - Displays a chronological record of 100 faults with the cause and the date and time of occurrence.
- **Trip data display**
  - Displays the sampling values of internal data and bit data ON/OFF status in the event of a fault.
- **Save of set data, load, and comparison**
  - The set data can be saved in the EPROM of the touch panel.
  - The saved data can also be loaded and compared with other saved data.

**Large LCD touch panel (option)**

This is a setting and monitoring tool for facilitating operation and monitoring on a 5.7-inch LCD.

- **Main functions of LCD touch panel**
  - Inverter start/stop
  - Setting, change and indication of control parameters
  - Bar graph display of actual value data
  - Indication of fault cause
    - (First fault/detailed indication)
  - Trend display
  - Test run, etc.

**Notes:**
1. The LCD unit can be mounted on the panel face (at the position where the console unit is mounted in page 9).
2. The display language is Japanese or Chinese.

**DDC loader for a maintenance tool (option)**

Although maintenance and adjustment can be performed from the touch panel mounted on the panel face, an optional DDC loader is available as a maintenance/adjustment tool. The DDC loader using a notebook computer is easy to use because of its interactive mode.

- **Main functions of maintenance tool**
  - Setting, change, indication and saving of control parameters
  - Running status display
  - Block diagram display, actual value indication, internal data listing
  - Indication of fault cause
    - First fault, detailed indication, trace-back data
  - Test run

**Display windows**

- **Operation monitoring window**
- **Trend data window**
- **Data setting window**
- **Internal data indication window**
- **Operation monitoring window**
- **Trend data window**
Standard specifications

<table>
<thead>
<tr>
<th>Full product name</th>
<th>FRENIC4600FM5e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage classes</td>
<td>3.3</td>
</tr>
<tr>
<td>Input</td>
<td>3- phase, 3000/3300V at 50/60Hz</td>
</tr>
<tr>
<td>Main circuit protection class</td>
<td>Class B</td>
</tr>
<tr>
<td>Control system</td>
<td>4 to 20mA</td>
</tr>
<tr>
<td>Frequency setting</td>
<td>0 to 10Hz</td>
</tr>
<tr>
<td>Frequency setting</td>
<td>0 to 5500s</td>
</tr>
<tr>
<td>Input impedance (major fault)</td>
<td>250 ohms</td>
</tr>
<tr>
<td>Input impedance (minor fault)</td>
<td>1M ohms</td>
</tr>
<tr>
<td>Load resistance</td>
<td>750 ohms</td>
</tr>
<tr>
<td>Cell control power source</td>
<td>AC main circuit (from secondary side of input transformer)</td>
</tr>
<tr>
<td>Control power source</td>
<td>3-phase, 3000/3300V AC</td>
</tr>
<tr>
<td>Frequency setting</td>
<td>0 to 10Hz</td>
</tr>
<tr>
<td>Frequency setting</td>
<td>0 to 5500s</td>
</tr>
<tr>
<td>Frequency setting</td>
<td>0.5% at max frequency (at analog frequency standard input)</td>
</tr>
<tr>
<td>Frequency setting</td>
<td>4 to 20mA/0 to 100%</td>
</tr>
<tr>
<td>Frequency setting</td>
<td>0 to 10V/0 to 100%</td>
</tr>
</tbody>
</table>

1. The applicable motor output is the reference value of Fuji Electric's standard 3.3 and 6.6kV, 4-pole motors.
2. Regenerative braking is not provided.
3. The rated output capacity is the value when the input and output voltage are 3.3 and 6.6kV, respectively. At 3.0 and 6.0kV, the output capacity must be multiplied by 0.9.
4. The inverter unit requires a dedicated input breaker.

Standard connection diagram

1. The inverter unit requires a dedicated input breaker.
2. At 3.0 and 6.0kV, the output capacity must be multiplied by 0.9.
3. The rated output capacity is the value when the input and output voltage are 3.3 and 6.6kV, respectively.
4. Regenerative braking is not provided.
### Dimensions

**3.3kV**

<table>
<thead>
<tr>
<th>Capacity (kVA)</th>
<th>Outline drawing</th>
<th>Dimension [mm]</th>
<th>Mass [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>390</td>
<td>Fig. 1</td>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>560</td>
<td></td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>770</td>
<td></td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>1150</td>
<td></td>
<td>450</td>
<td>450</td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td>1400</td>
<td>1400</td>
</tr>
<tr>
<td>1750</td>
<td></td>
<td>2200</td>
<td>2200</td>
</tr>
<tr>
<td>2600</td>
<td>Fig. 5</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>3500</td>
<td></td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>5200</td>
<td>Fig. 8</td>
<td>2200</td>
<td>2200</td>
</tr>
</tbody>
</table>

Note: (*1) The outline dimensions of the panel represent the maximum dimensions of a standard-capacity model. They may differ depending on the applicable motor capacity.

(*2) The structure is for maintenance from the front. Be sure to allow the maintenance space listed in column G of the above table.

(*3) A wiring duct is installed on the panel in Figs. 8 and 9 (height: 600mm).

(*4) A cooling fan is mounted on the panel. To assure maintainability and cooling performance, allow space of at least 300mm between the top of the fan and the ceiling.

(*5) The standard front face of the panel is a covered type (except for the control output panel). A door type can also be manufactured.

(*6) In the case of the 6.6kV type with a capacity of 2,500kVA and above, back to back installation (front/rear maintenance structure) reduces the panel width by approximately half. Contact us for the dimensions of this type.

(*7) The outline dimensions of the panel may be changed without notice. Contact us for details.

#### Wiring duct

- Min. G: 1200
- Min. F: 1100
- Min. D: 300

#### Ceiling

- Upper maintenance space: 2300mm
- Rear maintenance space: 2800mm

#### Contact us

For the dimensions of this type.

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**6.6kV**

<table>
<thead>
<tr>
<th>Capacity (kVA)</th>
<th>Outline drawing</th>
<th>Dimension [mm]</th>
<th>Mass [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>780</td>
<td>Fig. 2</td>
<td>2100</td>
<td>1500</td>
</tr>
<tr>
<td>1120</td>
<td></td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>1540</td>
<td></td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>2300</td>
<td></td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>3000</td>
<td></td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>3500</td>
<td>Fig. 5</td>
<td>2400</td>
<td>2400</td>
</tr>
<tr>
<td>5200</td>
<td>Fig. 8</td>
<td>2800</td>
<td>2800</td>
</tr>
<tr>
<td>7050</td>
<td>Fig. 7</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>10500</td>
<td>Fig. 3</td>
<td>5300</td>
<td>5300</td>
</tr>
</tbody>
</table>

Note: (*1) The standard front face of the panel is a covered type (except for the control output panel). A door type can also be manufactured.

(*2) In the case of the 6.6kV type with a capacity of 780kVA and above, back to back installation (front/rear maintenance structure) reduces the panel width by approximately half.

Contact us for the dimensions of this type.

(*3) The outline dimensions of the panel may be changed without notice. Contact us for details.
Contributes to energy saving

FRENIC4600FM5e inverter operation promises substantial energy-saving and carbon dioxide reduction.

In air-conditioning or pumping facilities, fans or pumps typically run at a constant speed even when the load is light. Adjustable speed control according to the load (air or liquid flow) through inverter operation greatly reduces energy consumption and maintains the maximum possible motor efficiency even at low-speed operation.

Example of application and energy-saving effect
The following example compares constant speed motor operation with valve (or damper) control, against inverter adjustable speed control operation, and shows the electric power saved.

Example conditions for calculation
Motor output: 1,000kW, for annual operation time 4,000 hours
Operation pattern:
- 85% flow for 1/2 of overall time (2,000 hours)
- 60% flow for the remaining half (2,000 hours)

Inverter operation (adjustable speed control operation with inverter)

- At 85% load of liquid flow (Q):
  - Required Power (P) = 91% × 1,000kW = 910kW
  - Annual power consumption:
    - 910kW × 2,000h × 1.17 = 3,340,000kWh
- At 60% load of liquid flow (Q):
  - Required Power (P) = 76% × 1,000kW = 760kW
  - Annual power consumption:
    - 760kW × 2,000h × 1.17 = 1,660,000kWh

- Annual energy-saving
  - 3,340,000 - 1,660,000 = 1,680,000kWh
  - (energy-saving = about 50%)
  - Carbon dioxide reduction = 100,800kg

Options

Field Web adapter (plusFSITE)
This adapter enables users to carry out remote monitoring of inverters promptly and easily with their own personal computers without using a dedicated system.

Main features

- Web server function
  - Inverters can be monitored from the browser of a personal computer. (Display screen can be changed if requested.)
- Mail sending function
  - Actions can be reported periodically from inverters.
- Installation and wiring both easy
  - A small and lightweight structure mountable on the front of the inverter panel
  - Connectable with the loader connector of an inverter (RS-232C interface)
  - Connectable with personal computers through LAN cable (IEEE802.3 10BASE-T)
- Protocol converting function
  - (Changeable from RS-232C to LAN)
- The corresponding drive unit is applicable to the FRENIC4600FM5e and other products of Fuji Electric.

LCD touch panel
The touch panel offers the following key loader functions:

- Start and stop of inverter
- Setting, change and display of control parameters
- Fault data display and fault resetting
- Data monitoring (LED display)

The contents of the above data are displayed on the LCD.

DDC loader
A loader using a notebook personal computer is available. The easy-to-use interactive type of loader offers the following functions:

- Start and stop of inverter
- Online setting, change, display and printing of control parameters
- Fault resetting
- Trace-back data
- Fault data display and printing
- Data monitoring

Analog output unit (AO unit)
Data can be output in analog mode during operation. Output data can be freely selectable among about 100 items by operating the touch panel.

Lifter
A special lifter for drawing out inverter cells
Wealth of functions to accommodate every need

**Selection of inverter capacity**

When selecting inverter capacity, select an inverter whose rated current value is larger than the operating current of the motor to be driven.

**Selection example 1**

For a 3.3kV, 60Hz, 300kW, 4-pole motor:
- Rated current value of motor: 65A

→ Select an inverter capacity of 300kVA (660A). (65 < 660A)

**Selection example 2**

For a 3.3kV, 60Hz, 800kW, 4-pole motor:
- Rated current value of motor: 130A

→ Select an inverter capacity of 770kVA (134A). (65 < 134A)

**Ordering Information**

When placing an order or making an inquiry, please state the following.

**Application of inverter**

**Load machine specifications**

- **Name:**  
  - Fan, Blower, Air compressor, Other ( )
- **Load torque characteristics:**  
  - Square-law speed, Constant torque, Constant output
- **Moment of load inertia after conversion into motor shaft (J):**
- **kg·m²**
- **Controllable range:**  
  - r/min to r/min
- **Rating Output:**  
  - kW, No. of poles: Voltage: kV
- **Frequency:** Hz
- **Speed control:**
  - Variable ( )
  - Constant ( )
- **Ambient conditions:**  
  - Install location: Indoor ( ), Outdoor ( )
  - Humidity: %RH, Temperature: °C, Altitude: m
  - Provision of air conditioning: Limit on carrying-in:

**Examples of applications**

- **Public facilities**  
  - Blower for blast furnace, Centrifugal fan, etc.
- **Building-related**  
  - Air-conditioning, elevators, etc.
- **Machine tool**  
  - Fan, Pump, etc.
- **Textile**  
  - Fine-spun yarn, etc.
- **Auto-related**  
  - Cooling fan, etc.
- **Paper, pulp, etc.**  
  - Paper fan, pump, etc.
- **Chemical**  
  - Cooling tower, etc.
- **Machinery**  
  - Cooling fan, etc.
- **Food, chemicals**  
  - Cooling fan, etc.
- **Petroleum**  
  - Cooling fan, etc.
- **Power transmission and distribution network**  
  - Control for power transformers, etc.
- **Automobile**  
  - Cupola blowers, etc.
Fuji Electric's inverters are manufactured in a factory that has acquired environment management system ISO14001 certification.