“FRENIC-eFIT” Environmentally Resistant Inverter Designed for Harshest Installation Conditions

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ABSTRACT

Inverters have been increasingly used in various industrial fields and are sometimes required to endure harsh environmental conditions without being installed in a controlboard. Fuji Electric has developed the “FRENIC-eFIT” as an environmentally resistant inverter especially designed for harsh installation conditions. In addition to protecting electronic components with a totally-enclosed enclosure that adopts a fanless cooling system, the unit has also eliminated thermal issues by utilizing SiC devices, which have characteristics of low-loss and heat resistance. Furthermore, we have applied our developed elemental technologies to mitigate high-speed switching noise while utilizing the technological know-how and field test results of Fuji Electric products to improve environmental resistance reliability.

1. Introduction

Recently, inverters have come to be used in various fields from the perspective of energy saving and productivity improvement, which has created an unprecedented need for use in harsh environments such as in a corrosive gas atmosphere and outdoors without being installed in a controlboard. To allow use in these environments and conditions, they need to adopt a fanless totally-enclosed structure to protect semiconductor devices and electronic components from corrosive gases and other adverse atmosphere. There are also many needs for using large-capacity equipment (up to 37 kW) in harsh environments as described above. For achieving a fanless totally-enclosed structure, thermal issues beyond those with conventional inverters must be resolved. Fuji Electric has developed the “FRENIC-eFIT” as an environmentally resistant inverter that resolves thermal issues and can be installed in harsh environments by using silicon carbide (SiC) devices characterized by low loss and heat resistance (see Fig. 1).

This paper describes the SiC device application technology, reliability improvement technology in terms of weather and corrosion resistance and heat dissipation design technology of the FRENIC-eFIT.

2. SiC Device Application Technology

SiC devices feature high-speed switching in addition to the low loss characteristics (see Fig. 2). High-
speed switching means that more noise is generated, which poses a major issue with their application. Table 1 shows the major specifications of the FRENIC-eFIT. The FRENIC-eFIT uses a sealed metal housing to improve environmental resistance so that it may also be used outdoors. This housing is also capable of magnetic shielding that allows the inverter to generate less radiation noise than general-purpose inverters with silicon insulated gate bipolar transistors (Si-IGBTs) mounted in an open housing (see Fig. 3). In terms of the degree of protection based on the IEC Standard, the FRENIC-eFIT has the degree of protection of a totally-enclosed type enclosure (IP55), while conventional general-purpose inverters are open type (IP00) with no dustproof or waterproof properties.

### Table 1 Major specifications of “FRENIC-eFIT”

<table>
<thead>
<tr>
<th>Item</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device adopted</td>
<td>All-SiC module</td>
</tr>
<tr>
<td>Installation environment</td>
<td>Conforms to environmental parameters by IEC Standard</td>
</tr>
<tr>
<td></td>
<td>Indoors and outdoors</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>50 °C (no output reduction)</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Design life of 10 years</td>
</tr>
<tr>
<td>Degree of protection</td>
<td>IP55 (IEC 60529)</td>
</tr>
<tr>
<td>Cooling system</td>
<td>Natural cooling (fanless)</td>
</tr>
<tr>
<td>Dimensions (mm)</td>
<td>W680 × D375 × H845</td>
</tr>
</tbody>
</table>

Fig.3 Radiation noise comparison (37 kW/400 V)

3. **Reliability Improvement Technology in Weather and Corrosion Resistance**

European manufacturers’ inverters with improved environmental resistance have catalogs and instruction manuals that indicate environmental parameters specified in the IEC Standard (IEC 60721-3-4: Classification of environmental conditions) to attract users’ attention to the environmental conditions for installation. The FRENIC-eFIT is required to be installed in industrial areas subject to emission of chemical contaminants with the environmental parameter specified in the IEC Standard of 4C4, due to the categories of business selected based on marketing and their factory environment. Accordingly, in addition to the 4 corrosive gases shown in Fig. 4, we determined environmental factors required in general industrial environment such as insolation, salt damage and oil. We then established evaluation items, content and judgment criteria by referring to the results of basic experiments with test pieces, environmental data gathered in field tests of sample units in cooperation with users, and Fuji Electric’s expertise about products to be installed in harsh environments, such as vending machines, outdoor controlboards, power conditioning systems for photovoltaic power generation, and rolling stock equipment. Figure 5 shows an example of a UV degradation test on coated sheet metal by using a sunshine carbon arc tester and the judgment criteria established.

With established evaluation items, content and
judgment criteria, we concurrently evaluated and quantitatively judged resistance to corrosive gases, weather and oil, which has allowed us to ensure unprecedented reliability of 10-year design life in terms of weather resistance and corrosion resistance.

4. Heat Dissipation Design Technology

Figure 6 shows the main circuit wiring and built-in peripheral devices of the FRENIC-eFIT. To eliminate the FRENIC-eFIT from using a controlboard, the housing must have fanless sealed structure while containing peripheral devices, such as an electromagnetic compatibility filter and direct current (DC) reactor. This may cause generation of more heat in the housing than general-purpose inverters, and hence temperature rises, which poses an issue of heat dissipation design. Heat dissipation design is necessary that prevents excessive temperature rise caused by the heat due to the power dissipation of devices in the housing.

Employment of SiC devices significantly decreases the generated loss. We release part of the power dissipation to outside of the housing by heat conduction through the cooling fins to adjust the overall temperature. First, we turned our attention to the SiC devices and power supply board, then the DC reactor, having the next high power dissipation, and electrolytic capacitors in the main circuit, which is easily affected by heat. We applied a layout that maximizes the contact area to increase heat transfer from these components to the cooling fins and fixed them by using a thermal conducting sheet (see Fig. 7).

We conducted heat simulation before and after taking this measure (see Fig. 8). One finding is that this measure alone could not limit the temperature of the board-mounted components to the specified temperature. The main cause was confirmed to be convection of the air heated by the DC reactor moving to the board side. As the most effective measure to deal with this, we considered use of a cooling fan for agitating inside the housing to homogenize and decrease the temperature in the housing. However, providing a cooling fan, which is a limited-life part, does not allow the product to be maintenance-free. Accordingly, to eliminate a cooling fan for agitation, we fitted a partition for shielding to prevent the air heated by the DC reactor from moving to the board side. However, it was confirmed by thermal simulation that completely partitioning compartments on the board and the main circuit component sides hampered convection arising from temperature difference and caused temperature unevenness in the housing. Therefore, we facilitated heat conduction by guiding the air heated by the DC reactor to the upper surface of the sheet metal while leaving the convection route. Finally, we successfully reduced the temperature rise of each component by approximately 18% and the temperature rise in the housing by approximately 8% to achieve a fanless sealed structure.

5. Specifications and Characteristics of “FRENIC-eFIT”

We decided as the first step of development to actively seek widespread use of the product for fan and pump equipment to build up a track record. As the second step, to apply it to process lines, which are important equipment, while further improving reliability. Accordingly, we equip the product with control functions of general-purpose inverters mainly with driving of fans and pumps in the first step and with control functions of high-performance inverters in the next step. These functions are built as a platform so that they can be achieved by replacing the control and
FRENIC-eFIT assumes standalone installation outdoors or in harsh environments and has the following 3 features:

(1) Customized logic function

The customized logic function is provided to allow users to individually customize functions (see Fig. 10). Control functions required for individual users’ machinery and applications can be built by combining various arithmetic functions in the inverter without using an external circuit composed of a simple programmable logic controller, external relays and timers. The number of programming steps is up to 200 and a programming tool that uses intuitive logic symbols and does not require any special development environment is available for free from Fuji Electric’s website.

(2) Bluetooth*-1-enabled touch panel

A remote-controlled Bluetooth-enabled touch panel (scheduled for release in FY2018) can be optionally selected and stored (see Fig. 11). The FRENIC-eFIT has a metal housing with a sealed structure that is partially open in the touch panel section. It is made waterproof with a special film and packing and additionally protected by using an acrylic decorative cover to protect it from the effect of electronic jamming while ensuring environmental resistance. By mounting this Bluetooth-enabled touch panel, users can remotely operate following features via a mobile device to meet their needs: editing and reading of function codes; monitoring of inverter information; real-time trace of the current, voltage and torque; and energy efficiency diagnosis.

(3) Installation structure

For outdoor installation of a controlboard that houses a general-purpose inverter and peripheral devices, standard works involve concrete casting for foundation and fixation of the controlboard using anchor bolts, which requires high costs and a long period of works and places a heavy burden on users. The FRENIC-eFIT is equipped with functions equivalent to or higher than those of this outdoor controlboard despite significant volume reduction to approximately a quarter. It can thus be mounted on a wall of an existing structure (see Fig. 12). In addition to the mounting feet provided as standard equipment, various options of installation method such as an adapter for wall mounting have been made available and the costs can be reduced by 70% and the work period by 60% for installation. The inverter can be mounted near the motor without having to care about the installation environment, which allows shorter output wiring and reduced wiring costs. Furthermore, reduction of motor surge and noise can be expected, eliminating the need for a surge filter and other measures against noise. This is another factor that eases the burden on users. Since the

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*1: Bluetooth: Trademark or registered trademark of Bluetooth SIG, Inc.
inverters can be installed near the motor, an operator can control the discharge rate with the inverter while checking the flow meter of the pump equipment, which has brought out comments from a user that it is very user-friendly in a field test.

6. Conformity to Overseas Standards

Fuji Electric plans to enter into a global market with the FRENIC-eFIT, which conforms to European functional safety standards, CE marking, UL Standards for the Americas and RoHS regulations*2. Starting in FY2018, we will acquire certifications in order (see Fig. 13).

7. Postscript

For employment of SiC devices for inverter products, we started with development of differentiating products that make use of the characteristics of SiC devices and acquired various types of knowledge. We intend to seek capacity increase using multiple SiC devices in parallel and build these applied technologies as a platform to apply to general-purpose models and other power electronics equipment.

References

*2: RoHS Regulations: Regulations of the European Union (EU) concerning restrictions on the use of certain hazardous substances in electrical and electronic equipment.
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