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| **Z-417** | |

# Engineering Requirement

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| VARIABLE FREQUENCY DRIVE - UNIT MOUNTED ON CHILLER | Z-417 | 2/12/02 |

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# SECTION A GENERAL

## 1 PURPOSE AND USE

1.1 This engineering requirement provides information and data needed to design, manufacture and apply a unit mounted liquid cooled, non-reversing Variable Frequency Drive (VFD) for induction motors on Carrier chillers:

1.1.1 Chiller Models:

1.1.1.1 19XR

1.1.1.2 23XL

## 2 PROCESS FOR CONSIDERATION OF USE ON A CARRIER CHILLER

2.1 All suppliers must be approved by CSS Development Engineering before they can be considered for standard production.

2.2 The request for consideration must be made to Carrier Engineering by the CSS Business Management Group.

2.3 Required minimum steps to supplier qualification include:

2.3.1 Complete drawing submittal, to include at least

2.3.1.1 Enclosure drawing

2.3.1.1.1 Outline

2.3.1.1.2 Mounting

2.3.1.1.3 Connection location

2.3.1.2 Control schematic

2.3.1.3 Power electronic schematic

2.3.1.4 Component layout

2.3.1.5 Drive electrical rating

2.3.1.5.1 Maximum Amps

2.3.1.5.2 Voltage range

2.3.1.6 Drive efficiency, matrix defining the below:

2.3.1.6.1 100%, 75%, 50%, 25% of Rated Load Amps

2.3.1.6.2 60, 50, 40, and 30 Hz

2.3.1.7 VFD price

2.3.1.7.1 Per unit base price, defined at the rated amperage of the unit.

2.3.1.7.2 Matrix of additional features, referenced to frame size.

2.3.1.8 Statement of compliance, with itemized exceptions list.

2.3.1.9 Development milestone schedule

2.3.1.10 Manufacture location

2.3.1.10.1 Drive module

2.3.1.10.2 Component consolidation

2.3.2 Design review with Carrier Engineering after complete submittal

2.3.3 Updated Submittal

2.3.3.1 Corrections and updates to the above.

2.3.3.2 Drawings for fabrication.

2.3.3.3 Assembly documents.

2.3.4 Prototype fabrication.

2.3.5 Qualification on a chiller.

2.3.6 Supplier Audit.

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## 3 TERMINOLOGY

3.1 Standard: Configurations of the drive that are sold as part of the base package and can be referred to by part number.

3.2 Standard Option: Options that are not part of the standard package but are pre-engineered and structured so that they can be easily provided to our end customer.
3.2.1 Complete design and process requirements must be in place.

3.3 Special Order Options: Customer requested options that have not been pre-engineered and require intervention from Carrier Engineering and the Supplier engineering departments.

## 4 APPLICATION

4.1 Compressor Motors: Special purpose hermetic, refrigerant cooled, low voltage 50/60 Hz three phase squirrel cage induction motors, driving variable torque refrigeration compressors.

4.2 VFD's will be selected based on the nominal line voltage requirements and the amp draw of the chiller compressor at the specific conditions as defined by the end customers full load operating requirements.

## 5 APPROVED SUPPLIERS

5.1 Drive Module Manufacturer
5.1.1 Rockwell Automation - Liqui-Flo AC Power Module
5.1.1.1 414 amp frame
5.1.1.2 500 amp frame
5.1.1.3 643 amp frame
5.2 Variable Frequency Drive Consolidator
5.2.1 American Controls Inc.

## 6 LITERATURE

6.1 Manufacturer must provide literature, documentation, and manuals as needed to provide instruction in the operation, maintenance, and trouble shooting of the VFD. The literature must be provided as a document package inside each drive enclosure.

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# SECTION B VARIABLE FREQUENCY DRIVE FUNCTIONAL REQUIREMENTS

## 1 CODE REQUIREMENTS

The VFD design and construction shall comply with the latest editions of the following standards applicable at the time of shipment.

1.1 UL standard 508 – Industrial Control Equipment (Devices)

1.2 UL Standard 508A – Outline of Investigation (Control Panels)

1.3 UL Standard 508C – Power Conversion Equipment (Drives)

1.4 National Electric Code (NFPA 70)

1.5 ANSI / NEMA standard publication, industrial control and systems, publication number.
- 1.5.1 ICS 1 General Rules
- 1.5.2 ICS 2 Contactors Overload relays etc.
- 1.5.3 ICS 3 Motor Control Centers, Medium Voltage Controller and Synchronous Controller
- 1.5.4 ICS 4 Terminal Blocks
- 1.5.5 ICS 5 Control-Circuit and Pilot devices
- 1.5.6 ICS 6 Enclosures

1.6 ANSI/ASHRAE 15, Safety Code for Mechanical Refrigeration.

## 2 RELIABILITY

2.1 System Reliability
- 2.1.1 As shipped: 99.9%
- 2.1.2 First 100 operating hours: 98.0%
- 2.1.3 First 3600 operating hours: 93.0%
- 2.1.4 First 15 years 90.0%

2.2 Component Reliability
- 2.2.1 First 3600 Operating hours: 99.8%

2.3 Annual Starting Cycles:
- 2.3.1 Nominal 6,000/year
- 2.3.2 Maximum 10,000/year

## 3 AMBIENT OPERATING CONDITIONS

3.1 External Ambient Air Temperature: 40°F to 104°F (5°C to 40°C)

3.2 Relative Humidity: 0% minimum to 98% maximum

3.3 Location Elevation: 6600-ft (2000m) maximum

## 4 SHIPPING AND STORAGE CONDITIONS

4.1 Temperature: -40°F to 140°F (-40°C to 60°C).

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4.2 Relative Humidity: 10% minimum to100% maximum (non condensing).

4.3 Packaging:

4.3.1 The VFD shall be adequately packaged to provide protection from exposure to the elements and damage encountered during normal shipping and sheltered storage. Internal packing materials shall be acceptable for use with static sensitive electronic components.

4.3.2 Packaging shall be returnable containers (reference UTC SP-9) unless the supplier has written approval from Carrier for non-returnable containers.

## 5 ENCLOSURE

5.1 Size Limitations Enclosure Target Dimensions

5.1.1 400-499 amp frames

5.1.1.1 Height: ≤ 41"

5.1.1.2 Width: ≤ 41"

5.1.1.3 Depth: ≤ 17"

5.1.2 500-650 amp frames

5.1.2.1 Height: ≤ 46"

5.1.2.2 Width: ≤ 50"

5.1.2.3 Depth: ≤ 22"

5.2 Mounting

5.2.1 The VFD enclosure shall be mounted on the top of the chiller condenser. Mounting brackets will be at the bottom of the enclosure.

5.2.2 The specific mounting requirements will be defined on the particular Carrier purchase drawing.

5.3 Enclosure environmental protection: NEMA 1

5.4 Line Connection Access

5.4.1 Location: Top

5.42 Type: Gasketed flange

5.43 Size:

5.43.1 400-499 amp frames: approximately 11½" x 11½"

5.43.2 500-650 amp frames: approximately 14” x 14”

5.44 Lug connections shall be located as to provide adequate clearance for easy connection by field electrician and in accordance with the National Electric Code.

5.5 Load Connection Access

5.5.1 Location: Rear of cabinet

5.5.2 Type: Grommeted opening. Cable will be protected from chafing against the hole in the enclosure.

5.5.3 Size: approximately 7.5" x 16"

5.5.4 Interconnecting Cable Shroud

The interconnecting cable shall be protecting by a sheet metal enclosure that is provided by Carrier Corp. This shroud will be mounted to the VFD enclosure in such a way as to allow flexibility to the many possible motor heights.

5.5.5 Termination from 6 terminal motor to three terminal VFD.

5.5.6 Interconnection Cables

5.5.6.1 Motor lugs will vary from 2"-14" from the rear of the enclosure.

5.5.6.2 Cables will carry separate part numbers from the VFD to allow VFD ordering flexibility.

5.6 Ground Lug

5.6.1 Sized for 4/0 gauge wire.

5.6.1.1 Line side connection.
5.6.1.2 Load side connection.
5.6.1.3 Internal connection.
5.6.2 Located with adequate clearance for easy connection.

5.7 Enclosure Access Door
5.7.1 Mechanically interlocked to the local disconnect.
5.7.2 Vertical Hinges with door stops.
5.7.3 Drip Guard.

5.8 Lifting for Installation on the Chiller
5.8.1 Lugs: Removable after installation
5.8.2 Location: Top

5.9 Enclosure Surface Preparation
5.9.1 All metal surfaces, inside and out, to be phosphatized, or cleaned and primed with a suitable corrosion inhibitor, finish enamel top coat.
5.9.2 Color Matched to Federal Standard 595a, #26231 (Carrier gray).

## 6 POWER EQUIPMENT AND CONFIGURATION

6.1 Line Voltage Requirements (voltages listed as optional may or may not be offered by all VFD suppliers and may require the use of a transformer):

| Nominal Voltage (Nameplate) | Applied Voltage Range |
|---|---|
| 6.1.1 200V/3 ph/60 Hz (optional) | 200-208V |
| 6.1.2 230V/3 ph/60 Hz (optional) | 220-240V |
| 6.1.3 380V/3 ph/60 Hz | 360-400V |
| 6.1.4 416V/3 ph/60 Hz | 401-439V |
| 6.1.5 460V/3 ph/60 Hz | 440-480V |
| 6.1.6 575V/3 ph/60 Hz (optional) | 550-600V |
| 6.1.7 230V/3 ph/50 Hz (optional) | 220-240V |
| 6.1.8 346V/3 ph/50 Hz (optional) | 320-360V |
| 6.1.9 400V/3 ph/50 Hz | 380-415V |

6.2 Line Voltage Tolerance: ± 10% of the Applied Voltage Range

6.3 Disconnect per National Electric Code
6.3.1 Line side termination

6.4 Power Conductor & Component Ratings
6.4.1 Standard (short circuit): minimum 30,000 amps symmetrical
6.4.2 Interrupt capacity: minimum 65,000 amps symmetrical

6.5 All control cable is to be stranded copper, 18 AWG minimum size type THNN, THWN MTW or equivalent.

6.6 Control & Oil Heater Power
6.6.1 Transformer
6.6.1.1 Voltages
6.6.1.1.1 Primary: Line supply
6.6.1.1.2 Secondary: 115V ±15%
6.6.1.2 Size
6.6.1.2.1 19XR: minimum 2.5 kVA
6.6.1.2.2 23XL:
6.6.1.2.2.1 Frame 1 & 2 1 kVA

6.6.1.2.2.2 Frames 4 2 kVA

6.6.1.3 Primary wired ahead of the main power disconnect switch.
6.6.1.4 Primary fused with disconnect switch or approved circuit breaker.

6.7 Oil Pump Power Supply
6.7.1 19XR product only.
6.7.2 Distributed from line supply ahead of main disconnect.
6.7.3 Fused Disconnect switch or approved circuit breaker.
6.7.3.1 Protection sized for 1.5 HP motor.
6.7.4 Oil pump interlock to be wired such that whenever the VFD is running power will be provided to the oil pump.

## 7 POWER ELECTRONICS AND COMPONENTS

7.1 AC-DC Converter
7.1.1 6-Pulse Rectification

7.2 DC Buss
7.2.1 3% Minimum Reactor

7.3 DC-AC Converter
7.3.1 Pulse Width Modulation
7.3.2 IGBT

7.4 Electrical Efficiency
7.4.1 Minimum 97.5% @ Full load, 60 Hz

7.5 Maximum Total Harmonic Current Distortion of the VFD, as defined by IEEE-519.
7.5.1 Standard Drive with bus inductor: 35% $I_h$ THD
7.5.2 With Optional 5% line reactor: 25% $I_h$ THD
7.5.3 With Optional Active Filter: 15% $I_h$ THD
7.5.4 With Optional 12-pulse rectification: 7% $I_h$ THD

7.6 Maximum Voltage Stress Levels, per NEMA MG1-30
7.6.1 Vpeak ≤ 1 kV
7.6.2 Rise time > 2 µs

7.7 Load-side Termination
7.7.1 Terminate for 6 wire motor, T1 - T6.
7.7.2 Power supply phase rotation A-B-C, motors rotate in the proper direction when phase A is connected to T1/T6, phase B is connected to T2/T4 and phase C is connected T3/T5.

## 8 VFD INTEGRAL CONTROLLER

8.1 Microprocessor-based VFD Control
8.1.1 Must interface with Carrier chiller controls, see Section C.
8.1.2 Speed control. Either volts per hertz or sensorless vector control will be accepted.

8.2 User Interface
8.2.1 Display shall be accessible from the external of the enclosure.
8.2.2 Operator must be able to perform a shutdown of the drive from the VFD control panel.

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8.3 Control Safeties
Protection shall be provided by VFD controller. Upon exceeding any of the control parameters the VFD will commence an immediate VFD shutdown. A fault condition can only be reset by the Chiller controller after the fault condition has returned to normal for at least 5 seconds.

8.4 Monitoring and protection (See Table 1 for list of instrumentation devices).

**TABLE #1 DEVICE MONITORING AND PROTECTION**

| Device | Description | Monitor | Protection |
|---|---|---|---|
| Voltage | Line voltage (Measurement error ± 2%) | 0 - 115% design | ± 5% design |
| Current | Line voltage (Measurement error ± 2%) | 0 - 125% design | |
| Ground Fault | Load Side<br>• Phase-to-phase<br>• Phase-to-ground | 0 - 75 amps | 5 - 40 amps |
| VFD Frequency | VFD Frequency feedback | 0 - 60 Hz | 10% from command Hz |
| VFD Start | Discrete contact of VFD start and run | Discrete | Timing |
| VFD Run | VFD has reached minimum speed | Discrete | Timing |
| VFD Temperature | Temperature of the VFD heat exchanger | 0 – 100°C | < 100°C |

## 9 VFD HEAT EXCHANGER

9.1 Heat exchanger design will be to cool the power electronics and the electromagnetics. The cooling fluid will be refrigerant R-134a.

9.2 Refrigerant cycle data
- 9.2.1 Refrigerant R-134a will be fed from the chiller condenser liquid to the VFD heat exchanger where it will absorb the heat from the VFD parasitic losses, vaporizing the refrigerant. The refrigerant vapor will then be returned to the Chiller evaporator.
- 9.2.2 Condenser saturated refrigerant pressure range: 120-85 Psia.
- 9.2.3 Cooler saturated refrigerant pressure range: 60-33 Psia.
- 9.2.4 Designed for minimum available differential pressure of: 35 Psid.

9.3 Temperature control
- 9.3.1 Refrigerant thermostatic modulating valve.
- 9.3.2 Temperature bulb will be embedded in the heat exchanger, referencing its operating temperature.
- 9.3.3 Final control system design will be coordinated with Carrier Engineering.

9.4 Refrigerant Piping
- 9.4.1 All internal enclosure piping will be brazed and leak tested prior to shipment to Carrier.
- 9.4.2 External refrigerant connection: o-ring seal.
- 9.4.3 See Carrier Engineering Requirement A-116 for leak requirements.

9.5 Heat exchanger refrigerant side pressure rating: 185 Psig.

9.6 Designed such that moderate condensation will not adversely effect electric or electronic parts.

9.7 The thermal inertia of the heat exchanger will design to allow 2 minutes of operation during start up without any flow from the cooling system, at loads below 30% of rated current.

## 10 TESTING, VFD SUPPLIER

10.1 Each VFD module will be tested at full power.

10.1.1 Operating temperature will be recorded.
10.1.2 Proper functionality will be verified and recorded.

10.2 Each completed VFD system will have an electrical verification test.
10.2.1 No load test.
10.2.2 Controls interface.
10.2.3 Proper functionality will be verified and recorded.

10.3 Each completed VFD system will have a leak test performed on all of the refrigerant piping per Carrier Engineering Requirement A-116.

10.4 Each completed VFD system will be tested and inspected in accordance with Carrier Engineering Requirement Z-421.

## 11 LABELING REQUIREMENT

The enclosure will have the following markings and labels:

11.1 Provide symbols and labeling to meet warning and safety requirements of the latest edition of all applicable codes, including but not limited to Occupational Safety and Health Administration Regulations (Standards-29 CFR) 1910.145 “Specifications for Accident Prevention Signs and Tags”, National Electrical Manufacturers Association (NEMA) Z535.1 through Z535.5, and Underwriter’s Laboratories (UL) 969.

11.2 Carrier Part Number.
11.2.1 Part number shall be defined by the Carrier VFD drawing.

11.2 Supplier Serial Number.
11.2.1 Serial number shall be unique for each VFD assembly.
11.2.2 Supplier must maintain traceability.

11.3 UL Certification Label.

11.4 A label stating “This equipment conforms with Carrier Engineering Requirement Z-417".

11.5 A label stating: "Important: The field wiring terminal connectors supplied within this device are suitable for use with copper conductors only. If user/installer selects aluminum he/she assumes responsibility for any and all failure that are related to these conductors".

11.6 A label stating: “Danger. Risk of electrical shock. Disconnect input power before servicing equipment. Wait 5 (five) minutes then check that the DC bus capacitors are discharged.”

11.7 In near proximity to the control power disconnect: “This Disconnect Removes Control Power”.

11.8 On units supplied with a circuit breaker or molded case disconnect switch: “Danger. Risk of electrical shock. The controller disconnect does not isolate all power from the enclosure.”

11.9 On units supplied without a circuit breaker or molded case disconnect switch: “Warning. Upstream disconnect required if controller is supplied without disconnect switch or circuit breaker.”

## 12 CUSTOMER OPTIONAL REQUIREMENTS

12.1 Objective. When selected, the design of these options must be developed and qualified as standard. See Section A-3.

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12.2 Shunt Trip Circuit Breaker. A shunt trip disconnect switch or breaker may be required in place of the disconnect.

12.3 Analog Meter Package
- 12.3.1 Volt Meter
- 12.3.2 Ammeter
- 12.3.3 Technical Requirement
  - 12.3.3.1 Measured on the line side of the drive.
  - 12.3.3.2 Selector switch for Voltage and Current to measure each phase.

12.4 12-Pulse Rectification

12.5 Line Reactor

12.6 Active Filter

## 13 SPECIAL OPTIONS

That may be required by our end customer on a job-by-job basis. Custom engineering by the supplier may be required.

13.1 NEMA 12

13.2 NEMA 4

13.3 Surge & Lightning Protector

13.4 CE Marking

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# SECTION C CONTROL INTERFACE REQUIREMENTS WITH INTEGRATED STARTER MODULE (ISM)

## 1 OBJECTIVE

The ISM is used to provide monitoring and control of the VFD by the Carrier Chiller controller. The ISM is to be purchased and installed by the VFD manufacturer.

## 2 ISM SUPPLY POWER, TERMINAL J1

2.1 115 Volt supply power to terminals LL1 & Terminals LL2. Power from control transformer Section B, 6.6.

## 3 ISM CONTACT INPUTS, TERMINAL J2

3.1 SPARE SAFETY, (J2; 1,2), Optional safety, no VFD connection is required.

3.2 ICE BUILD, (J2; 3,4), Optional safety used by customer to request Chiller Controls operate to build ice. No VFD connection is required.

3.3 REMOTE START, (J2; 5,6), Customer remote start request. No VFD connection is required.

3.4 STARTER FAULT, (J2; 7,8), Starter fault indication. VFD controls will use this to indicate the drive has shut down on a condition out of range.

3.5 1M AUX, (J2; 9,10), Start relay (1M) position indication. Verifies the position of the 1M relay.

3.6 2M AUX, (J2; 11,12), Run Relay. Indicates that the VFD as reached the preset minimum speed. Must be closed with 10 seconds or chiller controls will trip the VFD.

## 4 LINE VOLTAGE MONITOR, TERMINAL J3; L1-L3

Connects to the line voltage to monitor and verify that the line voltage is within specified design parameters. Transformer is required for line voltages over 575 volts.

## 5 LINE CURRENT MONITOR, TERMINAL J4; IL1-IL3

Connects to the current transformers (CT) that are monitoring the VFD line current. Used to monitor and verify that the line current draw is within specified design parameters. Interfaces through CT's defined as: Required instruments:

5.1 Three Current Transformers.

5.2 Located on the line side of the drive.

5.3 Ratio selection, such that the full load amps on the primary side translates to 3.75 -4.5 amps on the secondary. CT ratio shall be between 3:1 and 1000:1.

5.4 CT Burden: size for 2 ohms impedance.

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## 6 GROUND FAULT CURRENTS, TERMINAL J5; T1-T6

Provides either overall ground fault protection or phase to ground protection. This shall only be required if the VFD controller doesn't provide ground fault protection. Note phase to phase protection can be provided if the individual motor phases of the motor are brought back to drive, which is not required as part of this document.

6.1 Ratio of: 750:5.

6.2 CT Burden: size for 5 ohm impedance.

6.3 Provided as an option.

## 7 VFD HZ, TERMINAL J6; 1, 2

Analog input terminal that provides the feedback to the chiller controls as to what frequency the VFD is operating at. 0-5 VDC signal.

7.1 60 Hz applications
- 7.1.1 0 Vdc equates to 0 Hz
- 7.1.2 5 Vdc equates to 60 Hz

7.2 50 Hz applications
- 7.2.1 0 Vdc equates to 0 Hz
- 7.2.2 5 Vdc equates to 50 Hz

## 8 ISM DRY CONTACT OUTPUTS, TERMINAL J9

8.1 1CR, (J9:1,2), Start & Run Command. Closes at start and remains closed during the operation of the chiller. One of two devices that completes the circuit to the IM relay, see section 10.2.

8.2 TRANS, (J9:3,4), Transition Command. Control for a reduced voltage starter. Not used with the VFD application.

8.3 SHUNT TRIP, (J9: 5,6), Control for the shunt trip breaker/switch. Provides a contact for the control of a shunt disconnect/breaker. Shunt breaker/disconnect may be required as a customer required option.

8.4 EVAP PUMP, (J9: 8,7), Evaporator Pump run command. Customer connection to interface chiller controls with the evaporator brine pump starter.

8.5 COND PUMP, (J9: 9,10), Condenser Pump run command. Customer connection to interface chiller controls with the evaporator brine pump starter.

8.6 LO FAN, (J9: 11,12), Tower fan low speed run command. Customer connection to interface the chiller controls with the tower fan controller or starter.

8.7 HI FAN, (J9: 13,14), Tower fan high speed fun command. Customer connection to interface the chiller controls with the tower fan controller or starter.

8.8 TRIP ALARM, (J9: 15,16), Chiller trip or alarm contact for customer connection or monitoring.

## 9 ISM ANALOG OUTPUT TERMINAL, TERMINAL J8

9.1 VFD, (J8, 1,2) VFD frequency command signal, 4-20mA. Provides linear speed command to the VFD controller. Configured as follows:

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9.1.1 60 Hz applications.
- 9.1.1.1 4 mA equates to 0 Hz.
- 9.1.1.2 20 mA equates to 60 Hz

9.1.2 50 Hz applications.
- 9.1.2.1 4 mA equates to 0 Hz
- 9.1.2.2 20 mA equates to 50 Hz

## 10 RELAY DEVICE REQUIREMENTS

10.1 HPR, high pressure relay.
- 10.1.1 Relay can only be energized when the oil pump contactor is energized and the condenser high pressure safety switch has not been tripped. Signal from Carrier Controls.
- 10.1.2 Coil nominal voltage: 24 VAC
- 10.1.3 Minimum pick up voltage: 18 VAC
- 10.1.4 Maximum inrush: 60 mA
- 10.1.5 Coil side wired to terminals 17 & 43
- 10.1.6 Contact provides 120 volt signal to terminal J9, 1

10.2 1M, Start and run relay.
- 10.2.1 This relay will be energized by the ISM module, 1 CR, to indicate when the VFD is to start and indicate that the VFD is to remain running.
- 10.2.2 Coil Nominal Voltage: 120VAC
- 10.2.3 Minimum pick up voltage: 100 VAC
- 10.2.4 Coil side terminals, terminal J9,2 and J2,LL2.
- 10.2.5 Contact provides start run indication to the VFD controller.
- 10.2.6 Contact provides to terminals 50 &51

10.3 The ISM module needs to located as far as possible from the power electronics so that the harmonics & EMI will not interfere with its operation.

10.4 Carrier part number for the ISM # CES0130037.

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FIGURE 1
INTEGRATED STARTER MODULE