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USACE / NAVFAC / AFCESA	**UFGS-16268 (August 2003)**
Preparing Activity: NAVFAC	**Superseding**
UFGS-16268N (August 2003)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 25 June 2004

Latest change indicated by CHG tags.
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DIVISION 16 - ELECTRICAL

SECTION 16268

400-HERTZ (HZ) SOLID STATE FREQUENCY CONVERTER

08/04

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SECTION 16268

400-HERTZ (HZ) SOLID STATE FREQUENCY CONVERTER
08/04

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NOTE: This guide specification covers the requirements for the procurement, installation, and testing of 400 Hz solid state frequency converters.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.
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NOTE: These converters are used to supply 400 Hz electrical power to aircraft and ships in shore facility environments. Typical applications include aircraft operating in flight line conditions or in hangars, avionics shops, laboratories, training buildings, flight simulators, and computer rooms. This specification is not to be used for procurement of power converters installed on board aircraft or ships.
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NOTE: The following information shall be shown on the project drawings:

1. Show location of all equipment including converter, paralleling panels, remote monitoring and control panel.

2. Provide functional block diagram, single line diagrams, power, and control wiring interconnection diagrams, wiring diagrams, conduit entry diagrams, equipment elevations, limiting dimensions, and equipment ratings which are not covered in the specifications.

3. Design 400 Hz equipment rooms with working spaces as required by NFPA 70. Provide ventilation for equipment rooms based on 400 Hz components heat load generated when operating at 100 percent load. Provide 60 Hz convenience receptacles.

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NOTE: Ensure that the 400 Hz distribution system is properly coordinated including the ratings of the power cables, ground cables, circuit breakers, transformers, filters, rectifiers, and control equipment. When replacing a motor generator set with a solid state converter ensure that the existing feeders circuit protective devices will operate properly without damage to electrical devices including the solid state converter.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest guide specification. Use of SpecsIntact automated reference checking is recommended for projects based on older guide specifications.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C2	(2002) National Electrical Safety Code
IEEE C62.41	(1991) Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits
IEEE Std 1100	(1999) Recommended Practice for Powering and Grounding Sensitive Electronic Equipment - Emerald Book
IEEE Std 1159	(1995) Recommended Practice on Monitoring Electric Power Quality
IEEE Std 519	(1992) Recommended Practices and

	Requirements for Harmonic Control in Electrical Power Systems

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 158-1	(1970) Rating and Testing for Contactors

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2003) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ST 20	(1992; R 1997) Dry-Type Transformers for General Applications

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2002) National Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-PRF-24021	(Rev K) Electric Power Monitors, External Aircraft
MIL-STD-1399-300	(Rev A; Notice 1) Interface Standard for Shipboard Systems Section 300A Electric Power, Alternating Current (Metric)
MIL-STD-461	(Rev E) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-704	(Rev F) Aircraft Electric Power Characteristics

UNDERWRITERS LABORATORIES (UL)

UL 1012	(1994; Rev thru May 2000) Power Units Other than Class 2
UL 1449	(1996; Rev thru Jul 2002) Transient Voltage Surge Suppressors
UL 489	(2002; Rev thru May 2003) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
UL 506	(2000; Rev thru Feb 2004) Specialty Transformers

1.2 GENERAL REQUIREMENTS

Section 16050N BASIC ELECTRICAL MATERIALS AND METHODS, applies to this section with addition and modifications specified herein.

1.3 SUBMITTALS

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NOTE: Submittals must be limited to those necessary

for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy projects.

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy projects.

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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.][for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Frequency converter drawings[; G][; G, [_____]]

SD-03 Product Data

Frequency converter[; G][; G, [_____]]

SD-06 Test Reports

Performance tests[; G][; G, [_____]]

Submit within [15][_____] calendar days after completion of tests. Provide in accordance with the requirements set forth in paragraph entitled "Field Tests and Inspections." Certify tests were conducted on each converter in accordance with the paragraph entitled "Field Quality Control" and certify converter satisfactorily operated within specified limits. Report shall include copies of the test procedures and test data and results.

SD-07 Certificates

Qualifications of manufacturer[; G][; G, [_____]]

Work plan[; G][; G, [_____]]

Routine factory test plan, report, and procedures[; G][; G, [_____]]

Special factory test plan, report, and procedures[; G][; G, [_____]]

Field test plan, report, and procedures[; G][; G, [_____]]

UL listing[; G][; G, [_____]]

SD-09 Manufacturer's Field Reports

Routine factory tests report[; G][; G, [_____]]

Special factory tests report[; G][; G, [_____]]

Burn-in test[; G][; G, [_____]]

SD-10 Operation and Maintenance Data

Frequency converter, Data Package 5

[Remote Monitoring and Control Panel, Data Package 5]

Submit in accordance with Section 01781 OPERATION AND MAINTENANCE DATA.

1.4 QUALITY ASSURANCE

1.4.1 Frequency Converter Drawings

Furnish scaled drawings of enclosure outline including front, top, side views, and overall dimensions. Provide external power and control wiring and cable connections. Provide single line, schematic, and wiring diagrams. Drawings shall include details of input and output circuit breakers, contactors, rectifiers, surge protectors, and control devices. Drawings shall include conduit entry and exit locations. If parallel operation is included, provide an interconnection diagram.

1.4.2 Qualifications of Manufacturer

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NOTE: The experience clause in this section has been approved by a Level I Contracting Officer in accordance with the requirements of NAVFAC P-68. This clause may be used without further approval or request for waiver.

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Submit a certification that the manufacturer has a minimum of five (5) years' experience in the design, manufacturing, and testing of 400 Hz solid state frequency converters at the same or equivalent kVA and voltage

ratings for direct connection to aircraft electrical loads. When specifications require multiple converters operating in parallel, the manufacturer shall provide specific experience with equal or greater kVA rated converters.

The certification shall state that the manufacturer is experienced in manufacturing and testing solid state converters of an equivalent or greater kVA rating. Experience in manufacturing motor generator sets does not qualify as equivalent. Experience in manufacturing portable power units on wheels for temporary power does not qualify. The manufacturer shall be experienced in producing units for installation in permanent buildings in environmentally closed spaces or in weatherproof enclosures as applicable. The manufacturer shall also document that converters are designed for connection to non-linear loads typically encountered in the aircraft and shipbuilding industries. The manufacturer shall furnish maintenance engineering records from Navy shore installations to ensure 24,000 hour mean time between failures (MTBF) requirements. The manufacturer shall furnish documented experience with converters in various environmental conditions including exterior flight line, hangar, and environmentally enclosed spaces within buildings.

1.4.3 Work Plan

Submit a written schedule of dates of routine and special factory tests, installation, field tests, and operator training for the converter system. Furnish a list of instrumentation equipment for factory and field test reports.

1.4.4 Routine Factory Test Plan, Report, and Procedures

Submit 7 copies of test plans and procedures at least [21][_____] calendar days prior to the test being conducted. Provide detailed description of tests procedures, including test equipment and setups, to be used to ensure the converter meets the performance specification and explain the test methods to be used. As a minimum, the tests procedures shall include the tests required under the paragraph entitled "Routine Factory Tests."

1.4.5 Special Factory Test Plan, Report and Procedures

Submit 7 copies of test plans and procedures. Provide detailed description of tests procedures, including test equipment and setups, used to ensure the converter meets the performance specification and explain the test methods used. As a minimum, the tests procedures shall include the tests required under the paragraph entitled "Special Factory Tests."

1.4.6 Field Test Plan, Report, and Procedures

Submit 7 copies of test plans and procedures at least [10][15][_____] calendar days prior to the field tests. Provide detailed description and dates and times scheduled for performance of tests, and detailed description of test procedures, including test equipment and setups, used to ensure the converter meets the performance specification and explain the test methods to be used. As a minimum, the test procedures shall include the tests required under the paragraph entitled "Field Quality Control." Test reports shall include power quality measurement data collected in accordance with IEEE Std 1159.

1.4.7 UL Listing

Submit copies of current UL listings for the system, of the actual kVA rating or greater, with copies of the actual UL test results.

1.4.8 Routine Factory Tests Report

Submit within [15][_____] calendar days after completion of tests. Certify tests were conducted on each converter in accordance with the requirements set forth in paragraph entitled "Routine Factory Tests" and certify converter satisfactorily operated within specified limits. Report shall include copies of the test procedures and test data and results.

1.4.9 Special Factory Tests Report

Certify tests were conducted on a converter of the same design, construction and kVA and voltage rating to be provided and in accordance with the requirements set forth in paragraph entitled "Special Factory Test" and certify converter operated without malfunctioning within specified limits. Report shall include copies of the test procedures, instrumentation, and test data and results.

1.5 MAINTENANCE

1.5.1 Additions to Operation and Maintenance Manuals

In addition to requirements of Data Package 5, include the following on the actual frequency converter provided. Submit operation and maintenance manuals 2 weeks before operator training for Government review and approval.

a. A "one-line diagram" from service entrance to 400 Hz utilization panel or point.

b. A weatherproof, tear resistant plastic data sheet with operating instructions for each unit including startup, shutdown[, and paralleling] procedures.

1.5.2 Extra Materials

Furnish recommended manufacturer's spare parts list and schedule of prices for each type of converter and other equipment specified in this section. They shall include the following:

a. Power semi-conductors

b. Power filter capacitors

c. Plug-in logic cards

d. Output switching modules

e. Fuses

f. Indicator lamp/LED

PART 2 PRODUCTS

2.1 FREQUENCY CONVERTER

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NOTE: Include bracketed sentence for SOUTHNAVFACENGCOM projects only.
****

Provide frequency converter consisting of modular construction solid-state components for [50][60] to 400 Hz conversion, input/output devices, and ancillary control devices. Frequency converter shall be a standard product of the manufacturer and shall be the manufacturer's latest design that complies with the specification requirements. The 400 Hz frequency converters provided shall be products of the same manufacturer. The unit shall have a calculated MTBF exceeding [24,000][_____] hours as calculated when the converter is provided with yearly servicing and maintenance. The converter shall be UL or third party listed to comply with UL 1012. Circuit breakers operating at 400 Hz shall be designed and UL tested for 60 Hz operation and derated for 400 Hz operation.. The converter shall use a 12 pulse input rectification circuit. Provide startup and shutdown instructions posted on the front of the unit using engraved plastic plate. Provide a plastic encapsulated schematic diagram attached to the inside of the unit in clear view of maintenance personnel.

2.1.1 Electrical Characteristics

2.1.1.1 Input Voltage

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NOTE: For units 15 kVA and below the input voltage should be 208 volts and for units over 15 kVA the preferred input voltage is 480 volts. Using input voltage other than 480 volts will increase the cost and weight and decrease the efficiency of the converter. The input voltage shall be shown on the construction drawings.
****

[480Y/277][208Y/120][_____] V, three phase, four wire, grounded, [60][50] Hz. Converter shall provide rated output voltage when input voltage is varied plus or minus [10][_____] percent. Neutral currents shall not exceed [21][_____] percent of any individual phase current at no load and at full load.

2.1.1.2 Input Power Factor

Between 0.8 lagging and unity, under all conditions of steady state line and load variations specified herein.

2.1.1.3 Surge Protection

The converter shall be capable of sustaining an input surge described in and tested in accordance with UL 1449, location Category B, and continue to operate with no alarms within the specified tolerance.

2.1.1.4 Inrush Current

Measure and record inrush current and total harmonic distortion (THD) for

the first half cycle (8 to 10 milliseconds). The inrush current shall not exceed [100][_____] percent of the rated full load current. Conduct three tests and provide copies of waveform and THD analysis in test report.

2.1.1.5 Input Current Distortion

THD shall not exceed 5 percent of the fundamental with nominal input voltage while providing rated output up to 350 kVA. Individual harmonic content shall not exceed 3 percent of the fundamental.

2.1.1.6 Output Voltage

****

NOTE: Use MIL-STD-704, when 400 Hz power is required to power aircraft avionic equipment. Aircraft equipment is normally operated 115/200 V, three-phase, 400 Hz, grounded. MIL-HDBK-1004/5 contains aircraft electrical demand loads.

Use MIL-STD-1399-300, when 400 Hz power is required to power laboratory test benches simulating shipboard environments. Shipboard equipment in simulated shore laboratory environments normally operated on a 440 V, three-phase, 400 Hz, ungrounded system.

****

[115/200 V, three phase, 400 Hz, grounded][440 V, three phase, 400 Hz, delta connected ungrounded] system. [Adjustable to plus or minus 10 percent of the rated voltage]. The limits overvoltage and undervoltage shall be [as defined in MIL-STD-704][as defined in MIL-STD-1399-300 Type [II][III] power][plus or minus [2][_____] percent]. The phase rotation of the output voltage shall be clockwise sequence of [A-B-C][AB-BC-CA]. Converters shall be designed for compatibility with ship and aircraft power monitors complying with MIL-PRF-24021.

2.1.1.7 Power Output

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NOTE: Unit that will be used for providing power for aircraft should be sized for the type and number of aircraft to be supplied. The recommended sizes for units supporting aircraft are 60, 90, 120, or 250, 312, 325, or 375 kVA.

****

[_____] kVA at 0.8 power factor lagging.

2.1.1.8 Load Range

Operate into a load with a power factor between 1.0 and 0.8 lagging and into a non-linear load with a minimum crest factor for each phase current of [2.0][_____]. The crest factor is the ratio of the peak value to the root mean square (RMS) value for each half cycle of the voltage waveform measured over a one second period under steady state conditions.

2.1.1.9 Efficiency

****

NOTE: Use the table below to fill in the kVA and minimum efficiency.

Rating (kVA)	Minimum Percent Efficiency 50 Percent Load	100 Percent Load
5 - 14	80	90
15 - 39	86	90
40 - 99	87	91
100 - up	89	92

Adding EMI filtering and using the input voltage other than 480 volts for units with power rating larger than 15 kVA, will reduce the efficiency of the unit. If either EMI filtering or input voltage other than 480 volts is specified for units with power rating larger than 15 kVA, reduce minimum efficiency by 2 percent. If both are specified then reduce minimum efficiency by 4 percent.

****

The [_____] kVA units shall have a minimum efficiency of [_____] at 50 percent load and [_____] at 100 percent load.

2.1.1.10 No Load Input Losses

The frequency converter shall have no-load input losses no greater than [5] [_____] percent of the output kVA rating.

2.1.1.11 Overload/Overcurrent

Satisfactory overload/overcurrent operating time is based on no more than one overload in any 4 consecutive hours of operation:

Percent of Full Load	Satisfactory Operating Time
110 percent	60 minutes
125 percent	5 minutes
150 percent	2 minutes
200 percent	20 seconds
300 percent	6 seconds

2.1.1.12 Short Circuit

When [a bolted line-to-ground fault,] a bolted line-to-line fault, or a bolted three phase fault is applied to the unit, unit shall be capable of sustaining the short circuit current without damage until the protective device interrupts the fault.

2.1.1.13 Output THD

a. Balanced load:

(1) THD: Not to exceed [2][_____] percent line-to-line and line-to-neutral.

(2) Maximum single harmonic distortion: Not to exceed [1][_____] percent of the fundamental at the nominal voltage.

b. Unbalanced load: THD not to exceed 4 percent, line-to-neutral with 15 percent unbalanced load.

2.1.1.14 Amplitude Modulation

Shall not exceed 1/2 percent no load to full load.

2.1.1.15 Frequency Stability

Provide a high frequency crystal clock to control output frequency of the 400 Hz converter within plus or minus 0.5 percent for all operating conditions, including maximum and minimum specified input voltages, ambient temperature and relative humidity. The frequency regulation shall operate independent of supply frequency and load changes.

2.1.1.16 Phase Angle Regulation

Displacement angle between adjacent voltage phases shall be 2.09 rad 120 degrees plus or minus 0.0349 rad 2 degrees with balanced load and plus or minus 0.0698 rad 4 degrees with three phase 15 percent unbalanced load. A 15 percent unbalanced load is defined as:

a. Phase A at full rated single load.

b. Phase B at 85 percent of Phase A.

c. Phase C at 85 percent of Phase A.

2.1.1.17 Transient Output Voltage Recovery

****

NOTE: Use MIL-STD-704, when 400 Hz power is required to power aircraft avionic equipment.

Use MIL-STD-1399-300, when 400 Hz power is required to power shipboard equipment.

****

[In accordance with MIL-STD-1399-300 for Type [II][III] power.] [In accordance with MIL-STD-704.]

2.1.2 Environmental Rating

The converter shall operate satisfactorily from no load to rated full load under the following conditions:

a. Ambient temperatures ranging from 0 degrees C to 50 degrees C.

b. Relative humidity from [0 to 95] [_____] percent noncondensing.

c. Ambient pressures from sea level to [915] [_____] meters [3,000] [_____] feet.

2.1.3 Monitoring and Control Panel

Provide converter with an liquid crystal type control panel that is equipped with the following controls, indicators, instrumentation, data logging, diagnostics, and alarm functions.

2.1.3.1 Controls

a. Start/stop pushbutton.

b. Lamp/light emitting diode (LED) test - A push-to-test button or switch to test indicator lamps/LEDs.

[c. Alarm silence - A switch that shall disable the audible alarm.]

d. Alarm reset - A pushbutton to silence audible alarms.

e. Emergency power off.

[f. Master/slave switch.]

[g. Circuit breaker]

[h. Output contactor ON/OFF.]

[i. Output voltage adjust - Locate output voltage control inside converter enclosure, available for adjustment by maintenance personnel only when the door is open.]

2.1.3.2 Indicators

a. Input power available - Lamp/LED to indicate that the supply voltage is available.

b. Output power On/Off - Lamp/LED to indicate that the converter output voltage is available.

c. System alarm - Lamp/LED to indicate that a fault has been detected. This indicator shall be latched in the "ON" position whenever an alarm condition described in paragraph entitled, "Alarm Annunciator," is detected and shall remain "ON" until the alarm reset pushbutton is pressed.

d. Indicating lamp/LED to indicate that the alarm silence switch is in the disable position.

e. Audible alarm.

[f. Master operation mode - Lamp/LED to indicate that the converter is operating in parallel mode and is operating as the master unit.]

[g. Slave operation mode - Lamp/LED to indicate that the converter is operating in parallel mode and is operating as a slave unit.]

[h. Output contactor "ON".]

[i. Aircraft interlock bypass - Lamp/LED to indicate that the Aircraft Interlock has been bypassed.]

2.1.3.3 Instrumentation

a. Elapsed time meters (in hours).

b. Output voltmeter selector switch having three [phase-to-phase positions for monitoring delta outputs in accordance with

MIL-STD-1399-300][phase to neutral positions for monitoring wye voltage outputs in accordance with MIL-STD-704] and one "OFF" position.

c. Output ammeter selector switch having three phase positions and one "OFF" position.

d. Output frequency meter, 390 to 410 HZ scale, having a 400 HZ center with an ON-OFF switch.

2.1.3.4 Alarm Annunciator

The unit shall be capable of detecting the following abnormal conditions, sounding an audible alarm and illuminating individual indicator lamp/LEDs that are clearly identified:

a. Input overvoltage.

b. Input undervoltage.

c. Output undervoltage.

d. Output overvoltage.

e. Output overload.

f. System alarm.

g. Control logic failure.

h. Frequency deviation.

i. Overtemperature.

j. Logic power supply failure.

2.1.4 Input/Output Devices

Provide fully-rated, three-pole, UL approved devices for control of [50] [60] Hz input and 400 Hz output from the converter. Devices and cables operating at 400 Hz shall be derated in accordance with IEEE Std 519.

2.1.4.1 Circuit Breaker

Conform to requirements of UL 489. Units operating at 400 Hz shall be derated for 400 Hz operation.

2.1.4.2 Input Circuit Breaker

Provide converter with an UL listed input circuit breaker as an integral part of the converter. Breaker shall be operable from the front of the converter.

****
NOTE: Select either output circuit breaker or output contactor.
****

[2.1.4.3 Output Circuit Breaker

Provide converter output with a non-automatic manual circuit breaker with appropriate frame size and shunt trip coil derated for 400 Hz operation. Circuit breaker shall be tripped by the unit's OFF circuit [local or remotely activated] and when any circuit identified in the paragraph entitled "Protective Control" causes the system to shut down. Output breaker shall be operable from the front of the unit.

][2.1.4.4 Output Contactor

Provide converter output with an automatic magnetically-held contactor with interlock circuit. Output contactor shall be of sufficient capacity to handle rated load, overload, and available short circuit current. Contactor shall be tripped by any circuit identified in the paragraph entitled "Protective Control." Output contactor shall be electrically interlocked with ON/OFF circuitry so that when the frequency converter is shut down, the contactor shall open immediately and remain open. [Conform to the requirements of IEC 158-1.]

][2.1.4.5 Aircraft Interlock Circuit

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NOTE: Aircraft interlock circuit is not normally required when providing power to Navy aircraft. Use only when requested by Air Force or other DOD claimants.

****

Interlock circuit shall determine the presence or absence of the 28 VDC feedback signal from the aircraft. Interlock circuit shall not allow the output disconnect to close if the 28 VDC signal is not present. If the output disconnect is closed when the 28 VDC is lost, the disconnect shall open within 2 seconds. Converter shall contain terminal block points for the connection of two 12 AWG wire from the aircraft cable assembly for the interlock circuit. Interlock circuit shall not draw more than 20 milliamperes from the aircraft's 28 VDC circuit. For testing purposes, provide a switch inside the converter with two positions:

a. Normal - For aircraft loads.

b. Bypass - For testing with dummy load or no load, or for use with aircraft with no 28 VDC.

]2.1.5 Protective Controls

Provide circuitry for the following protective controls.

a. Input undervoltage.

b. Input overvoltage.

c. Loss of phase.

d. Loss of input power.

e. Door interlock - When any access door is opened, the interlock circuitry shall open the 60 Hz input device [and 400 Hz output device] and not allow the input [or output] device to close. For

maintenance purposes, provide a bypass switch to defeat the interlock circuitry.

f. Output overvoltage - Protect by tripping output devices for instantaneous overvoltage of 30 percent or more and for 10 to 30 percent overvoltage lasting more than 0.25 second.

g. Output undervoltage - Protect by preventing the closing of the output disconnect until the output voltage is 95 percent of the rated output. If, after closing, the voltage decreases to below 90 percent for longer than 5 seconds, provide relaying to trip output devices utilizing a field-adjustable time-delayed circuit with a range of 4 to 10 seconds.

h. Output frequency - Protect by tripping output devices for frequency change in excess of plus or minus 5 percent of the rated output frequency (400 HZ).

i. Output overload.

j. converter overtemperature protection - Provide a thermistor to detect SCR mounting surface and activate automatic shutdown if the temperature exceeds 80 degrees centigrade or 177 degrees F.

[2.1.6 Electromagnetic Interference Limits

****
NOTE: This is an additional cost item and reduces converter efficiency. EMI filtering should not be specified unless specifically requested by the user.
****

Comply with MIL-STD-461 for Class C2 equipment.

][2.1.7 Automatic Line Drop Compensation

Provide automatic line drop compensation - 0 to 7 percent adjustable internally.

][2.1.8 Paralleling

Provide frequency converter capable of being paralleled to other like units. Regulate and control units operated in parallel by a master unit. Design controls associated with paralleling of the units such that each frequency converter can operate as a stand alone unit, or as either a slave or master unit in a parallel system. Units shall parallel and synchronize within a 50 millisecond recovery time. Share the total load equally within plus or minus [____][5] percent by each unit. [Provide manual paralleling which permits a paralleled unit to be added or removed from the system without interrupting the operation of other units.]

][2.1.9 Auto Restart

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NOTE: Auto restart should be considered when the converter is installed in a remote location that is not readily accessible to operating personnel and maintaining 400 Hz power is critical to operations. Use of auto restart should be studied carefully to

ensure that it does not create a potential personnel safety hazard.

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After a total input power outage the unit shall be capable of automatically restarting and re-energizing loads upon restoration of normal power. Provide units with a manual/auto restart switch. If this requirement requires a backup battery power supply this shall be provided. When interlock circuit has been interrupted or when interlock is in the maintenance position manual restart, the system should not restart.

][2.1.10 Built-In Test Equipment

Frequency converter shall include built-in test equipment which monitors both primary circuits and protection circuits of the unit. Provide visual indication to assist diagnosis of unit failures to a modular level. Provide visual indication of converter status using cabinet mounted light emitting diodes.

][2.1.11 Magnetic Devices

Provide Class 180 power magnetic transformer and inductors in accordance with NEMA ST 20 and UL 506. The limits of Class 180 shall not be exceeded at the maximum specified ambient temperature and at 100 percent load.

]2.1.12 Acoustical Noise

****

NOTE: The following table serves as a guide for establishing the maximum allowable sound pressure level for each kVA rating. The designer should take into consideration that converters are inherently noisy when locating the unit.

Rating (kVA)	Maximum Allowable Acoustical Noise (dBa)
5 - 14	58
15 - 39	62
40 - 99	68
100 - 249	70
250 - up	72

****

A maximum continuous acoustical noise level of [_____] dBa (A weighted scale).

2.1.13 Assembly Construction

Provide enclosures suitable for [indoor][outdoor][corrosive][direct spray] [_____] environments in accordance with NEMA 250, Type [1][3][3R][4X][12]. Arrange to provide required louvers, cooling air, entry and exit provisions for equipment within enclosures. Construct unit(s) so that components, with the exception of control and monitoring components, are totally enclosed within the enclosure. Electronic circuits including power circuits shall be modular construction readily accessible for maintenance, repair and module replacement from the exterior of the enclosure. Provide permanent identification tags for wiring. Uniquely identify each wire. Use the same identification system in the wiring diagrams in the Operation

and Maintenance Manual. Provide each enclosure with a finish coat over a substrate which has been provided with a rust inhibiting treatment. [Provide two finish coats for outdoor enclosures.] Color shall be the manufacturer's standard color.

2.1.14 Nameplates

As specified in Section 16050N BASIC ELECTRICAL MATERIALS AND METHODS.

[2.2 REMOTE MONITORING AND CONTROL PANEL

Provide remote monitoring and control panel and circuitry. Connect to clearly and permanently labeled terminal blocks located inside the converter's enclosure. Provide the circuitry such that indicator lamp/LED information and control function(s) can be extended from the terminals to a remote location in the future.

a. Pushbutton or switch for de-energizing the output terminals.

b. Indicator lamp/LED showing the unit status (energized or not energized).

c. Indicator lamp/LED showing the output circuit breaker position (open or closed).

d. System alarm.

]2.3 SOURCE QUALITY CONTROL

2.3.1 Routine Factory Tests

****
NOTE: Recommend requiring 1.0 and 0.8 power factor tests at the factory and submit reports. Then only perform 1.0 power factor test in the field and compare the results.
****

[The manufacturer shall test every converter to ensure compliance with the specification.] For tests which require full load, use [0.8 lagging power factor] [and] [1.0 power factor] unless otherwise noted. All measurements shall be true RMS measurements. Measurements shall be obtained in accordance with IEEE Std 1159. Tests shall include the following:

a. Input current: Operate converter at low and high input voltage at no load and full load. Measure and record current in each phase [and neutral if the neutral conductor is connected to the converter input.]

b. Input power factor: Operate at low, nominal, and high input voltage at no load, half load, and full load. Measure and record input voltage, input phase currents and input power factor.

c. Output voltage, power, power factor, and voltage regulation: Operate at low, nominal and high input voltage at 25 percent, 50 percent, and 100 percent loads. Loads shall have [0.5 lagging power factor], [unity power factor] and [0.8 leading power factor] and non-linear load shall be a three phase full wave bridge rectifier with a load required to produce the specified current

crest factor. Measure and record output voltage, output current (peak and RMS), output current wave form, power factor and frequency. Verify output voltage and frequency remain within specified regulation limits.

d. Efficiency: Operate at nominal input voltage at half load and full load. Measure and record input voltage, input current, input power factor, output voltage, output current, and output power factor. Calculate the unit efficiency.

e. No load losses: Operate at no load and nominal input voltage. Measure and record input voltage, input current, input power, input power factor, and output voltage.

f. Burn-in Test: Before delivery, burn-in all units [under full load conditions for at least [24][_____] hours] [by cycling units [6][_____] hours "ON" under full load conditions and [3][_____] hours "OFF" at no load conditions for at least [4][_____] complete "ON" cycles.]

g. Include Fourier Waveforms depicting Harmonic Order and Harmonic Magnitude in test reports.

2.3.2 Special Factory Tests

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NOTE: Recommend requiring 1.0 and 0.8 power factor tests at the factory and submit reports. Then only perform 1.0 power factor test in the field and compare the results.
****

[The manufacturer shall test [one][_____] unit[s] of each rating and size converter to assure compliance with the specification.] [Conduct tests on production model of converters of the same design, construction and kVA rating provided.] For all tests which require full load, use [0.8 power factor][1.0 power factor] unless otherwise noted. The tests shall include the following:

a. Surge protection: Apply input surges in accordance with IEEE C62.41, Category B and monitor output. Conduct a minimum of three consecutive successful tests on each unit listed. Confirm there is no interruption to 400 Hz output power and voltage stays within specified regulation tolerances.

b. Inrush current: After applying power to the converter, conduct a minimum of three inrush current tests. Measure and record maximum inrush current after the first half cycle (8 to 10 milliseconds).

c. Input current distortion: Operate at nominal input voltage at no load, half load, and full load. Measure and record the THD for the current in each phase.

d. Overload/overcurrent: Operate at nominal input voltage with loads listed below:

Percent of Full Load	Minimum Operating Time
110 percent	60 min
125 percent	10 min
150 percent	2 min
200 percent	20 sec
300 percent	6 sec

Monitor output to confirm there is no 400 Hz power interruption.

e. Short-circuit: Apply [a bolted line-to-ground], bolted line-to-line, and bolted three phase fault directly to the output terminals of the unit. Conduct a minimum of three consecutive successful tests on each unit. Provide unit capable of carrying the fault current until the integral system protective devices interrupts the fault with no damage to the unit. Provide recordings or display of short circuit current during short circuit tests.

f. Output THD: Operate at nominal input voltage at no load and full load with balanced and 15 percent unbalanced load. A 15 percent unbalanced load is defined as follows:

(1) Phase A at full rated single phase load.

(2) Phase B at 90 percent of Phase A

(3) Phase C at 85 percent of Phase A

Measure and record the THD for the line-to-line voltage, [line-to-neutral voltage] of each phase current.

g. Amplitude modulation: Operate at no load and full load. Measure and record percentage of amplitude modulation.

h. Phase angle regulation: Operate at no load and full load with balanced and 15 percent unbalanced loads. Measure and record displacement angle between adjacent voltage phases. A 15 percent unbalanced load is defined as follows:

(1) Phase A at full rated single phase load.

(2) Phase B at 85 percent of Phase A.

(3) Phase C at 85 percent of Phase A.

i. Transient recovery: Operate at steady state conditions at 75 percent rated load. Apply a [15][_____] percent load change, as an added load then as a dropped load. Measure and record recovery time and output voltage deviation limits. Provide recordings or display of output voltage during transient recovery test.

j. Acoustical noise: Operate at no load, 50 percent and 100 percent of full load. Measure continuous steady sound pressure level 1525 mm 5 feet horizontally from the center of each side of the convertor at a point 1525 mm 5 feet above the floor. Decibels (dB) are referenced to 20 micropascal.

[k. Electromagnetic interference (EMI) test: [EMI test shall meet the requirements of MIL-STD-461, Part 9, for Class C2 equipment.] [Certified test results on units of the same design shall be acceptable.]]

[l. Paralleling: Operate at nominal input voltage at 50 percent and 100 percent of full load. Measure and record the output voltage, output current and power factor provided by each individual unit.]

PART 3 EXECUTION

3.1 INSTALLATION

Install products to operate at 400 Hz in the same manner as specified in other sections of this specification for products operating at [50] [60] Hz, unless indicated or specified otherwise. Conform to the requirements of NFPA 70 and IEEE C2 and to manufacturer's instructions and recommendations.

3.1.1 Equipment

3.1.1.1 Floor Mounted

Provide proper floor mounting channels and install in the concrete floor slab in accordance with the manufacturer's drawings and instructions and as indicated. Align, level, and bolt or weld units to channels to allow easy withdrawal or insertion of removable components and to permit proper operation and maintenance of equipment.

3.1.1.2 Wall Mounted

Bracket mount, but otherwise install as required for floor-mounted units.

3.1.2 Grounding

****

NOTE: Insert appropriate Section number and title in the blanks below using format per UFC 1-300-02.

****

In accordance with NFPA 70 and as specified in [Section 16402 INTERIOR DISTRIBUTION SYSTEM] [_____].

3.1.3 Wiring and Conduit

****

NOTE: Conductors, circuit breakers, and devices operating at 400 Hz shall be derated as follows:

Circuit Breakers

	Derating Factor
E Frame (100 A)	**0.87**
F Frame (225 A)	**0.85**
J Frame (600 A)	**0.82**
K Frame (1200 A)	**0.74**

AWG	Cable Derating Factor
#2	0.9877
#1	0.9675
#1/0	0.9481
#2/0	0.9167
#3/0	0.8831
#4/0	0.8483

****

****
NOTE: Insert appropriate Section number and title in the blank below using format per UFC 1-300-02.
****

Provide Type XHHW or THHN with stranded copper conductors wiring for 400 Hz circuits. Provide wiring for 400 Hz circuits in non-magnetic conduit, aluminum or PVC. Provide wiring and conduit for 60 Hz circuits as specified in [Section 16402 INTERIOR DISTRIBUTION SYSTEM] [_____].

3.1.3.1 Conduit

Use aluminum conduit for exposed feeders. Do not install aluminum conduit underground or encased in concrete. Use aluminum fittings and boxes with aluminum conduit. For underground or concrete encasement use PVC.

3.1.4 Manufacturer's Representative

The manufacturer's representative shall place the system in operation and make necessary adjustments to ensure optimum operation of the equipment. The manufacturer's representative shall have at least 2 years of practical experience in the installation and testing of 400 Hz solid state frequency converters.

3.2 FIELD QUALITY CONTROL

3.2.1 Performance of Acceptance Checks and Tests

Perform field tests and conduct inspections. Provide labor, equipment tests instruments, and incidentals required for the tests [including load banks], except the Government will furnish electricity [and test loads].

3.2.2 Instruments

The test plan shall list make and model and provide functional description of the test instruments and accessories and shall describe the setup of the tests to be conducted. Provide test instruments capable of measuring and recording or displaying test data at a higher resolution and greater accuracy than specified for the converter's performance. The test instruments used in the field tests shall have current and valid calibration stickers issued by an approved calibration laboratory. Verify calibration and adjustments of converter instruments provided prior to field tests. Instruments shall be calibrated for 400 Hz operation when measuring 400 Hz signals.

3.2.3 Performance Tests

Conduct converter performance tests under the supervision of the manufacturer's representative. Successfully complete the preliminary operation, control and protective devices check prior to performing load and transient tests. If the converter fails to operate within the specified limits during any of the performance tests the Contractor shall discontinue the test and shall make necessary repairs to correct the failure and retest the converter.

3.2.3.1 Preliminary Operation

Inspect the converter and make adjustments necessary to assure proper operation in accordance with the manufacturer's instructions. Operate frequency converter at 0, 25, 50, 75, and 100 percent of rated full load. Measure and record the output voltage, current, frequency, and THD at each load. Verify converter is operating within specified limits at each load level.

3.2.3.2 Control and Protective Device Checks

Operate each control, switch, input/output device that is capable of being operated manually a minimum of three times, demonstrating satisfactory operation each time. Perform operation test on each protective device to ensure that devices functions properly. After each operation measure and record the converter output frequency, voltage and current. Verify converter is operating within specified limits.

3.2.3.3 Load Test

Operate each unit continuously a minimum of 2 hours at 100 percent rated load and 6 seconds at 300 percent of rated load. Test shall be at [unity power factor][0.8 lagging power factor]. After each operation measure and record the converter output frequency, voltage and current. Verify converter is operating within specified limits. Perform resistive load test in field.

3.2.3.4 Transient Tests

Conduct transient tests on each converter by instantaneously removing 50 percent of rated and then 100 percent of rated load. Provide recordings or displays of voltage and frequency during each transient test, and indicate on the recordings and display the time intervals and acceptable limits for voltage and frequency. Repeat each transient test three times, record the results of each test. Verify converter is operating within specified limits.

3.2.3.5 Harmonic Distortion Tests

Perform harmonic distortion tests as described in IEEE Std 519 and IEEE Std 1100. The Contractor shall provide test equipment and instrumentation required for the tests. Tests shall be conducted with a distortion analyzer with test leads within 3 feet of the frequency converters input terminals. Test data shall include total harmonic distortion amplitudes of all individual harmonics presented in a bar graph format, and fast fourier analysis (FFT) of the harmonics up to the 37th order.

3.3 DEMONSTRATION

3.3.1 Instructing Government Personnel

Provide field training to Government personnel on the operation and maintenance of the converter provided. As a minimum the training shall include [2][_____] hours of instruction on the theory of operation and [4][_____] hours on the repair and maintenance of the converters. The instructor shall be approved by the manufacturer of the unit provided. Training shall be approved by the Contracting Officer at least 2 weeks in advance. The Government may record, video and audio, the training sessions and use these recordings to train personnel, on the operation and maintenance of the converter system. Provide two copies of video or audio tapes, if used, in the training sessions to the Contracting Officer.

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NOTE: Suggestions for improvement of this specification will be welcomed using the Navy "Change Request Forms" subdirectory located in SPECSINTACT in Jobs or Masters under "Forms/Documents" directory or DD Form 1426. Suggestions should be forwarded to:

Commander
Naval Facilities Engineering Command
NAVFAC Criteria Office
1510 Gilbert Street
Norfolk, VA 23511-2699

FAX: (757) 322-4416 or DSN 262-4416

EMAIL: specs@efdlant.navfac.navy.mil

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-- End of Section --