SAE INTERNATIONAL

AEROSPACE RECOMMENDED PRACTICE

ARP5015™ REV. B

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Superseding ARP5015A

(R) Ground Equipment - 400 Hertz Ground Power Performance Requirements

RATIONALE

Modifications are made within the document for the new generation aircraft electrical systems, update the external document references and general updates and corrections.

ARP5015B has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE

1.1 This SAE aerospace recommended practice (ARP) covers the requirements for external ground power equipment supplying 115/200 V, three-phase, 400 HZ output power measured at the aircraft receptacle. All forms of 400 Hz ground power including mobile and fixed systems are addressed by this document.

1.2 The intent of this document is to provide specifications for engine generators (alternator), motor generators, and solid-state converters tailored for performance with modern aircraft, applicable to all unless otherwise noted. Modern aircraft are requiring higher quality power without interruption which places new constraints on the ground power units (GPUs) such as unity power factor and no-break-power-transfer (NBPT). The protective trip limits are designed to allow a two-tier protection utilizing both the aircraft's electrical power generating systems (EPGS) and the GPUs protection. Some of these specifications will place some new design constraints on the manufacturers of GPUs but will help promote compatibility with old and new generation aircraft with all types of ground power equipment.

1.3 While GPUs are designed to provide the same quality of power as the aircraft's EPGS, there are differences in rated capacity. Engines powered GPUs must be sized for the peak kw specified which is why a 125% overload is specified for GPUs. As an example, increasing the size of the prime mover to match the aircraft's EPGS typical 150 to 200% overload rating would not be practical

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP1247	Aircraft Ground Support Equipment - General Requirements
SAE J1175	Bystander Sound Level Measurement Procedure for Small Engine Powered Equipment

2.2 ANSI Accredited Publications

Copies of these documents are available online at http://webstore.ansi.org/.

ISO 1540	Aerospace - Characteristics for Aircraft Electrical Systems
ISO 6858	Ground Support Electrical Supplies - General Requirements
ISO-461-1	Connector for ground electrical supplies - Part 1: Design, performance and test requirements
ISO-461-2	Connector for ground electrical supplies - Part 2: Dimensions

2.3 U.S. Government Publications

Copies of these documents are available online at http://quicksearch.dla.mil.

MIL-STD-704F	Electric Power, Aircraft, Characteristics and Utilization of

2.4 UL Publications

Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 1446-1980	Systems of Insulating Materials - General Revised 3/86

2.5 NEMA Publications

Available from National Electrical Manufacturers Association, 1300 North 17th Street, Suite 900, Arlington, VA 22209, Tel: 703-841-3200, www.nema.org.

NEMA MG-1	NEMA Standards Publication - Motor and Generators (N/A to Solid-State)
NEMA PE-1	Uninterruptable Power Systems
NEMA 250	Enclosures for Electrical Equipment

2.6 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC/EN 60204-1	Safety of Machinery - Electrical Equipment of Machines - General Requirements
IEC/EN 61558-2-6	Safety of Transformers - Reactors, Power Supply Units and Similar Products for Supply Voltages up to 1,100 V - Part 2-6: Particular Requirements and Tests for Safety Isolating Transformers and Power Supplying Units Incorporating Safety Isolating Transformers.
IEEE-519	Guide for Harmonic Control and Reactive Compensation of Static Converters

2.7 ATA Publications

Available from Airlines for America (A4A), 1301 Pennsylvania Avenue, NW, Suite 1100, Washington, DC 20004, Tel: 202-626-4000, www.airlines.org.

ATA-Spec 101	Specification for Ground Power Equipment Technical Data

2.8 Other Publications

AN-3114, AN-3440	Army/Navy 6-Pole Socket/Plug Reqmts. (MS90362-MS25486 Cable:MS90328)
BSI 2G-219	General Requirements for Ground Support Electrical Supplies for Aircraft
DFS-400	Eurostandard 400 Hertz Systems (Obtained from Flughafenverband ADV, Friedrichstrasse 79, 10117 Berlin, Germany, e-mail info@adv.aero or http://adv.aero/der-verband/ansprechpatner)
UL 1012	Standard for Safety Power Units Other Than Class 2
CSA C22.2, No. 107.1	General Use Power Supplies

2.9 DEFINITIONS AND ABBREVIATIONS

This glossary of terms is included as part of this document for use in its interpretation.

2.9.1 ADJUSTABLE VOLTAGE RANGE

The range adjustment, as controlled by the regulator, to enable checking over and under voltage protection devices.

2.9.2 ALTERNATOR SPEED

The nominal speed at which the alternator operates to produce 400 Hz.

2.9.3 ALTITUDE

The maximum height above sea level at which the unit must operate and maintain characteristics within recommended limits.

2.9.4 AMBIENT TEMPERATURE RATING

The temperature range in degrees in which the unit must operate and maintain characteristics within recommended limits.

2.9.5 BREAK TRANSFER

The mode of transferring the aircraft load from aircraft power source to ground power source or vice versa whereby power to the aircraft is momentarily interrupted.

2.9.6 CREST FACTOR

The ratio of the peak voltage to the rms voltage.

2.9.7 DEAD FRONT

Constructed so that there are no exposed live parts on the front of the assembly.

2.9.8 DIELECTRIC TESTS

The high voltage impressed across the primary and secondary of a transformer and between a component and the chassis of the unit. This test is used to check insulation characteristics.

2.9.9 FREQUENCY OF VOLTAGE MODULATION

The component frequencies which make up the modulation envelope waveform.

2.9.10 FREQUENCY MODULATION

The cyclic variation of instantaneous frequency about a mean frequency during any steady state load. Frequency modulation, in percent, is calculated by taking maximum frequency minus minimum frequency times 100 and dividing this value by maximum frequency plus minimum frequency. Frequency modulation is a measure of the stability of the power system's frequency regulation.

2.9.11 FREQUENCY MODULATION RATE

The rate of change of frequency due to frequency modulation when plotted against time.

2.9.12 FREQUENCY REGULATION

The band the output frequency stays within except during transients.

2.9.13 FREQUENCY TRANSIENT RECOVERY

The time required for the output frequency to recover to and remain within the prescribed limits after load application or removal.

2.9.14 FREQUENCY TRANSIENTS

The maximum instantaneous deviation of the output frequency from the frequency regulation band.

2.9.15 GROUND POWER UNIT (GPU)

A rotating or static source supplied by an external ground facility to source electrical power while the aircraft is on the ground whether it is a point of use or centrally located system.

2.9.16 HIGHEST PHASE VOLTAGE LIMITING

A means of limiting the highest phase voltage of the unit output during any unbalanced load condition.

2.9.17 INDIVIDUAL HARMONIC

The rms value of any individual harmonic voltage that is expressed as a percentage of the fundamental.

2.9.18 INPUT CURRENT DISTORTION

The total harmonic distortion is a measurement of the harmonic distortion present in a signal and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.

2.9.19 LINE DROP COMPENSATION

A system of increasing the unit output voltage in proportion to the current and power factor in the output cable(s) such that the voltage is held constant at the aircraft receptacle.

2.9.20 NO BREAK POWER TRANSFER (NBPT)

The mode of transferring the aircraft load from aircraft power source to ground power source, or vice versa, whereby the aircraft and ground power sources are simultaneously connected to the aircraft load and in parallel with each other, possibly out of synchronization.

2.9.21 NOMINAL VOLTAGE RATING

The root-mean-square line-to-neutral and line-to-line voltage at which the unit output is rated. The unit is normally set such that output voltage is maintained at this value.

2.9.22 OUTPUT TERMINALS

The terminals on the ground power unit side of the output power feeders. This is considered to be the point of regulation for the ground power unit.

2.9.23 OVERLOAD RATING

The normal overload value expressed in kVA at 0.8 power factor for specified time.

2.9.24 PHASE VOLTAGE BALANCE WITH BALANCED/UNBALANCED LOAD

The maximum deviation of any of the three phase voltages from the average of the three phase voltages with a designated three-phase load. The percent unbalance is calculated by taking maximum deviation of any one line-to-neutral voltage from the average of the three phase voltages times 100 divided by the average of the three phase voltages.

2.9.25 PHASE VOLTAGE DISPLACEMENT WITH BALANCED/UNBALANCED LOAD

The maximum deviation in degrees from 120 degrees between phases of the alternator voltages during designated load conditions.

2.9.26 PRIME MOVER

The source of power for driving the alternator.

2.9.27 REGULATOR SENSING

The means by which the voltage is sensed and fed to the voltage regulator.

2.9.28 SHORT-CIRCUIT CURRENT

The maximum current carrying capacity of the GPU deemed unsafe and detrimental to the GPU’s functionality.

2.9.29 TEMPERATURE RISE

The rise in degrees above ambient for components of the unit.

2.9.30 TOTAL HARMONIC CONTENT

The total RMS voltage remaining when the fundamental component is removed. This value is determined by calculating the square root of the sum of the squares of the individual harmonics and expressing this value as a percentage of the fundamental.

2.9.31 TOTAL LIFE EXPECTANCY

Defined to be the hours/years of use from time of delivery of the equipment to the using activity until its identity is destroyed by classifying it as salvage and/or subject to cannibalization.

2.9.32 TRIP

Occurs when the output is turned off or the output contactor is opened.

2.9.33 TYPE OF MOUNTING

The means of mounting the unit and controls.

2.9.34 UNIT

Refers to the complete power package such as the prime mover, alternator, and all associated equipment and systems.

2.9.35 UNIT RATING

The full load value (rated continuous) expressed in kVA at specified power factor. The unit shall be capable of operating at any power factor from 0.8 lagging to 1.0 (unity).

2.9.36 VOLTAGE MODULATION

The cyclic variation about an average of the AC peak voltage during any steady state load. The modulation envelope is formed by a continuous curve connecting each sine wave peak. Voltage modulation in percent is calculated by taking maximum voltage minus minimum voltage times 100 and then dividing this value by maximum voltage plus minimum voltage.

2.9.37 VOLTAGE REGULATION

The band the output voltage stays within except during transients.

2.9.38 VOLTAGE REGULATION STEADY STATE

The band that the output voltage stays within a fixed load.

2.9.39 VOLTAGE TRANSIENTS

The maximum momentary deviation of the output voltage from the steady state voltage as a result of step load changes.

2.9.40 VOLTAGE TRANSIENT RECOVERY

The time required for the output voltage to recover to and remain within the prescribed limits after load application or removal.

3. TECHNICAL REQUIREMENTS

3.1 EQUIPMENT SPECIFICATIONS

All AC voltage characteristics are in reference to the aircraft receptacle, unless otherwise stated.

3.1.1 Output Rating

The engine generator (alternator), motor generator, or solid-state converter shall be of sufficient capacity to produce the rated kVA at a power factor ranging from 0.8 lagging to 1.0 (unity), and at specified overload limits, for the altitude and temperature range in which the equipment will be operated.

3.1.2 Alternator Speed

The designation shall be based on the continuous operating speed of the prime mover, and design of the alternator, to produce 400 HZ. Not applicable to solid-state converters.

3.1.3 Temperature Rise

Components of an alternator shall have insulating properties meeting NEMA MG-1 Standards. solid-state converters shall utilize a minimum of UL Class 180 Transformer insulation systems in any magnetics greater than 1000 VA.

3.1.4 Dielectric Tests

All magnetic components shall have dielectric strength test performed to check insulation characteristics.

3.1.5 Power Supply Safety Standards Testing

For solid-state converters, where this condition is required by the customer for operational or safety reasons, testing to meet UL 1012 and CSA 22.2 safety standards.

3.1.6 Continuous Rating

The continuous kVA rating shall be at a specified power factor ranging from 0.8 to 1.0 (unity). Reference 3.6.4 for details involving environmental conditions and deratings associated with the equipment rating.

3.1.7 Overload Rating

The normal overload rating shall be 125% of rated kVA for 5 minutes at a specified power factor ranging from 0.8 to 1.0 (unity). Reference 3.6.4 for details involving environmental conditions and deratings associated with the equipment rating.

3.1.8 Nominal Voltage Rating

The AC system shall be a three-phase, four-wire Wye system with grounded neutral having a nominal voltage of 115/200 V. The grounded neutral shall be solidly tied to the unit chassis ground with sufficient capacity in the tie to handle maximum ground fault current for a minimum of 5 seconds.

3.1.9 Adjustable Voltage Range

The adjustable voltage range shall be sufficient, in unloaded condition, for checking over-voltage and under-voltage and subsequent protective devices.

3.1.10 Regulator Sensing

Regulator sensing shall be enough to provide the specified output voltage levels within this document.

3.1.11 Highest Phase Voltage Limiting

A highest phase voltage limiting system is recommended in the voltage regulator to limit the highest phase voltage to 124 V during unbalanced load conditions.

3.1.12 Line Drop Compensation

A system of automatic line drop compensation shall be incorporated in the voltage regulator to provide constant voltage at the aircraft receptacle, based on the cable length, regardless of current. Minimum compensation capability shall be 5% at rated load for a single output.

3.1.13 Voltage Regulation Steady State

The voltage at the aircraft receptacle shall stay within the steady state limits shown in Figure 1 for any rated load condition.

3.1.14 Voltage Transients

The transient response shall be limited to the operating area shown in Figure 1 with step load changes equivalent to the full continuous load rating shown in 3.1.6.

3.1.15 Short-Circuit Current

The short circuit protection system shall remove power if current exceeds the overload capacity of the GPU. No current limit voltage fold back mode shall be used.

3.1.16 Voltage Modulation

The modulation of phase voltage (including the effects of frequency modulation) shall not exceed 3.5 V when measured as the peak-to-valley difference between the maximum and minimum peak voltages reached on the modulation envelope over a period of at least 1 second.

3.1.17 Frequency of Voltage Modulation

The frequency components of the voltage modulation envelope waveform shall not exceed 100 Hz.

3.1.18 Phase Voltage Balance with Balanced Load

The maximum deviation of any of the three-phase voltage from the average of the three-phase voltages shall not exceed 1% with a balanced three-phase load.

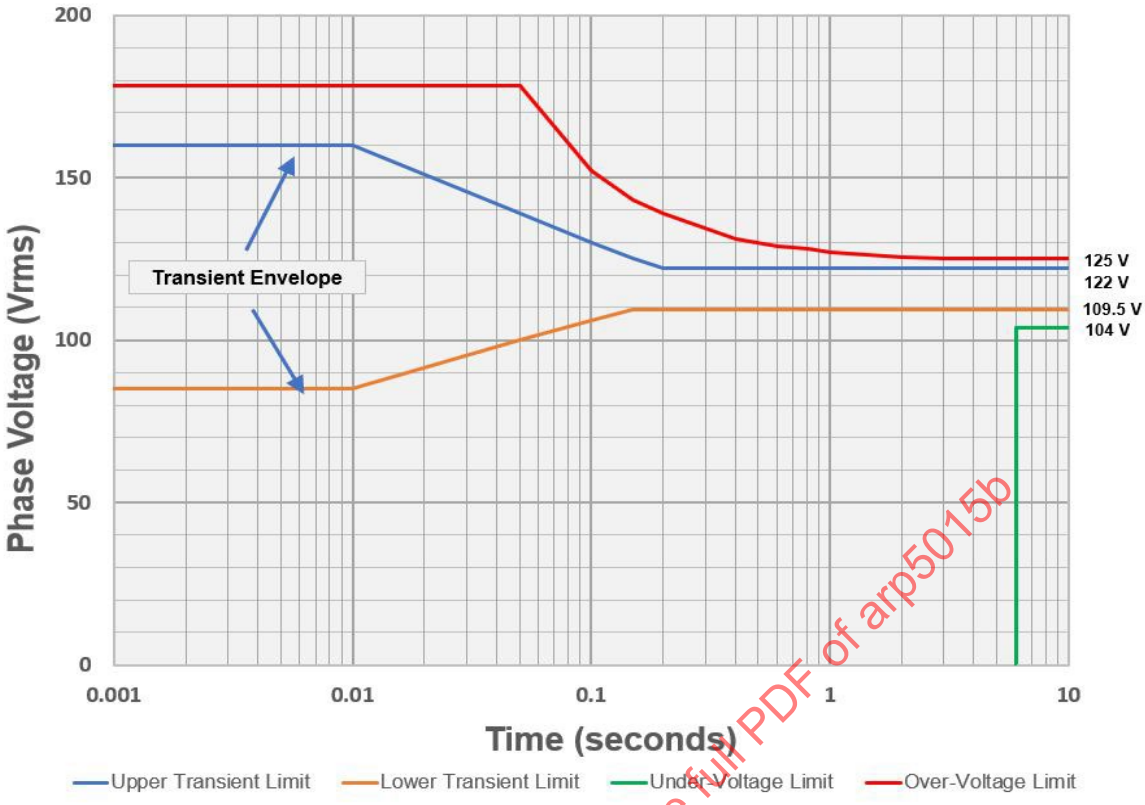

Figure 1 - Voltage compliance and protection

3.1.19 Phase Voltage Displacement with Balanced Load

The phase voltage displacement with a balanced three-phase load shall be within the limits of 120 degrees ± 2.5 degrees.

3.1.20 Phase Voltage Balance with Unbalanced Load

The maximum deviation of any of the phase voltages from the average of the three-phase voltages shall not exceed 4% with 1/3 rated current at 0.8 power factor lagging on any one phase and no load on the other two phases when measured at aircraft receptacle.

3.1.21 Phase Voltage Displacement with Unbalanced Load

The phase voltage displacement with a 1/3 rated current unbalanced load under 40-kVA, and 1/6 above 40-kVA, shall be within the limits of 120 degrees ± 4 degrees between any phase (line to neutral) voltages.

3.1.22 Individual Harmonic

The rms value of any individual voltage harmonic shall not exceed 2% of the fundamental (rms) when measured from line-to-line and line-to-neutral at no load and rated kVA (linear load) at 0.8 power.

3.1.23 Total Harmonic Content

The total harmonic content of the output voltage shall not exceed 3% of the fundamental (rms) when measured from line-to-line and line-to-neutral at no load and rated kVA (linear load) at 0.8 power factor. The total harmonic content of the output voltage shall not exceed 4% of the fundamental (rms) when measured from line-to-line and line-to-neutral for a 1/3 rated current unbalanced load.

3.1.24 Crest Factor

The crest factor of the alternator shall be 1.414 ± 0.09.

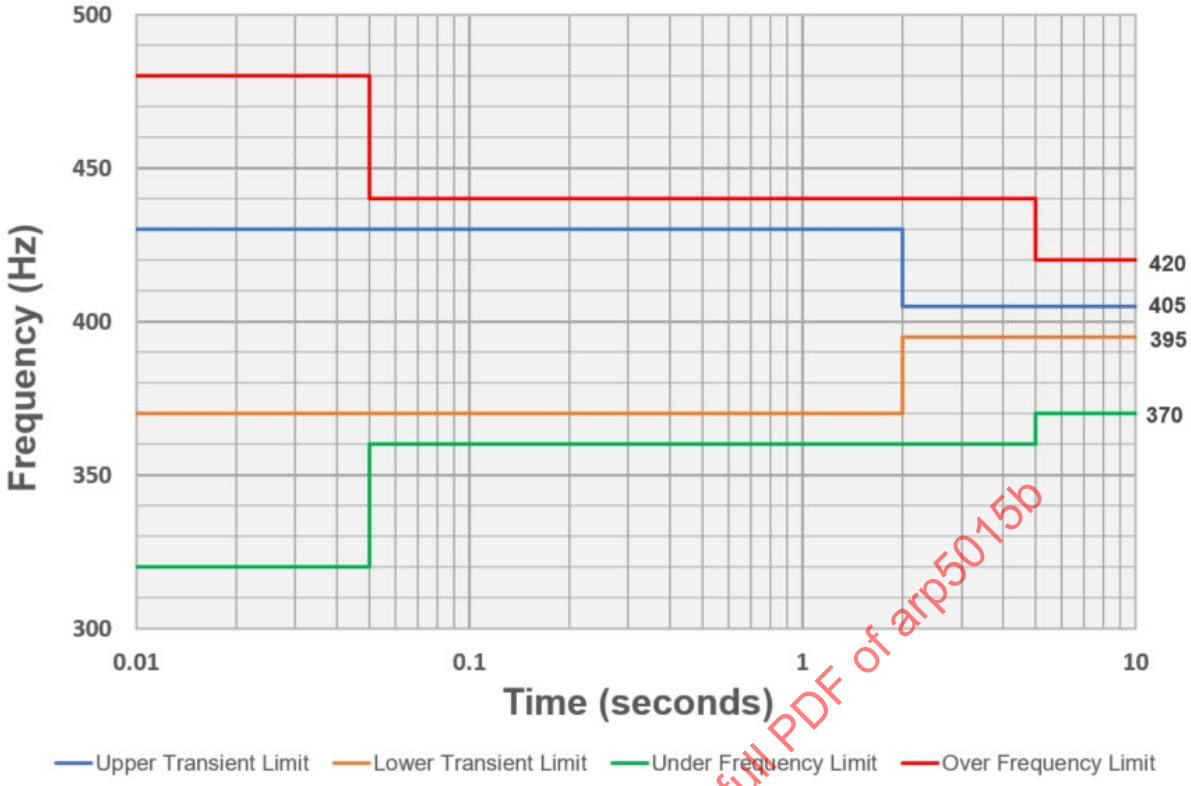

Figure 2 - Frequency compliance and protection

3.1.25 Frequency Regulation

The output frequency shall stay within 400 Hz ± 5 Hz at all steady state loads up through full rated load.

3.1.26 Frequency Transients

The instantaneous frequency shall not be greater than 430 Hz or less than 370 Hz during full load application or removal as shown in Figure 2.

3.1.27 Frequency Transient Recovery

Output frequency shall recover to and stay within 400 Hz ± 5 Hz in 2 seconds as shown in Figure 2.

3.1.28 Frequency Modulation

The output frequency modulation shall not exceed 0.25% of the steady state frequency for all loads up to and including full rated load.

3.1.29 Frequency Modulation Rate

The rate of frequency modulation rate shall not exceed 13 Hz per second.

3.1.30 No Break Power Transfer (NBPT)

The unit must be able to operate in an uninterrupted fashion during NBPT and maintain voltage and frequency within specified limits with onboard and ground power sources out of synchronization by as much as ±30 degrees, ±2 Hz frequency, ±10 Vrms for maximum time duration of 100 ms. If the NBPT conditions are more severe, the unit's protection device(s) may be activated.

3.1.31 Phase Rotation

Phase rotation shall be A-B-C.

3.2 Personnel Safety

3.2.1 Where necessary, the system shall include personnel and equipment protection from contact to exposed hot surfaces, exhaust gases and possible exposure to volatile elements (i.e., fuel, oil, grease, etc.) within the equipment.

3.2.2 For prime movers, the fuel tank and exhaust shall be located appropriately and shielded to prevent exposure to electrical or engine components during filling or operating conditions.

3.2.3 Each unit shall offer safety to personnel operating or in vicinity of an operating unit. control panel doors should require a tool or key to open to prevent entrance by anyone other than authorized personnel when practical. inside the control panel, any voltage over 30 Vrms shall be located, guarded, or enclosed to prevent accidental contact. suitable warning labels shall be provided if internal voltages decay slowly after shutdown.

3.2.4 All rotating or moving parts shall be shielded to prevent accidental contact while unit is in normal operating mode. Labels or safety signs shall be provided. Where applicable to local and national standards, fire suppression systems shall made available.

3.2.5 Control panel shall have unrestricted access to operating personnel and be adequately illuminated for both day and night operation. All control functions to be clearly identified and grouped according to their function. The controls to be designed for easy operation while wearing foul weather clothing.

3.3 Equipment Protection

The facility shall automatically remove the power from the output terminals when the AC line-to-neutral exceeds curve of Figure 1 at output terminals.

3.3.1 The facility shall automatically remove the power from the output terminals when the average AC line-to-neutral voltage drops below curve of Figure 1 at output terminals.

3.3.2 The facility shall automatically remove the power from the output terminals when the frequency drops below the limits shown in Figure 2.

3.3.3 The facility shall automatically remove the power from the output terminals when the frequency exceeds the limits shown in Figure 2.

3.3.4 The facility shall automatically remove the power from the output terminals when the output exceeds the overload rating of the GPU. Overload protective should have an inverse time characteristic and should operate to protect the unit if a short-circuit occurs within the GPU or its distribution system. No current limiting voltage foldback practices shall be used.

3.3.5 The facility shall be provided to prevent the GPU from being connected to the aircraft when the rotation is not consistent with a ABC, three-phase, Y configuration.

3.3.6 The protective system shall include fault indication that shall be easily identified.

3.3.7 E/F Interlock Circuit

3.4 Current Quality Check

When commanded on by the operator, the facility power shall be provided to the aircraft for a period of 2.5 s without the aircraft providing the returned interlock signal on Pin F. This will allow time for on-board aircraft controls. It shall not be possible for the facility to supply power to the aircraft through the interlock connections.