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DEPARTMENT OF DEFENSE
INTERFACE STANDARD

SECTION 300B

ELECTRIC POWER, ALTERNATING CURRENT

AMSC/NA FSC 1990

FOREWORD

1. Preamble. This military standard is approved for use by the Department of the Navy and is available for use by all Departments and Agencies of the Department of Defense.

2. Purpose. This section defines the standard interface requirements for and the constraints on the design of shipboard user equipment that will utilize shipboard alternating current (AC) electric power.

3. Nature of the interface. In any system involving power source, distribution network, and load (user equipment), the characteristics at the system and user equipment interface are mutually dependent on the design and operation of both. In order for the electric power system to perform within the established tolerances, it is necessary to place constraints on the power source, the distribution system, and the user equipment. This interface standard defines the electric power system characteristics. User equipment constraints are also established.

4. Structure. The technical content first delineates the characteristics of the shipboard electric power system at the interface in terms of voltage, frequency, continuity, and voltage waveform. Constraints on user equipment design and installation, which are necessary to achieve shipboard compatibility with and to assure these characteristics, are then established. Finally, test requirements are specified to verify conformance of user equipment to this standard.

5. Invoking the standard. The Principal Development Activity (PDA) will consider the mission requirement of the user equipment being developed or acquisitioned. The PDA will then select those conditions under which the user equipment is to operate and those conditions, which the user equipment will withstand without failure, but not necessarily, operate normally. The PDA will also specify those tests commensurate with the equipment's mission, which will ensure the user equipment's satisfactory operation, the user equipment's compatibility with the shipboard electric power system and other equipment, and the equipment's survival.

6. NATO coordination and standardization. The standard characteristics of AC electric power supplied for U.S. Navy ships have been coordinated with NATO standardization documentation, where applicable. In particular, the standard characteristics of Type I and Type II power conform to corresponding power types specified in STANAG 1008 (Edition Number 8).

7. Numerical quantities. Numerical quantities are expressed in metric (SI) units.

8. Contact information. Comments, suggestions, or questions on this document should be addressed to Commander, Naval Sea Systems Command, ATTN: SEA 05M2, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to commandstandards@navy.mil, with the subject line "Document Comment". Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at http://assist.daps.dla.mil.

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1. SCOPE

1.1 Scope. This military standard section establishes electrical interface characteristics for shipboard equipment utilizing AC electric power to ensure compatibility between user equipment and the electric power system. Characteristics of the electric power system are defined and tolerances are established, as well as requirements and test methods for ensuring compatibility of shipboard user equipment with the power system. The policies and procedures established by MIL-STD-1399 are mandatory. This section and the basic standard are to be viewed as an integral single document for use in the design and testing of electric power systems and user equipment.

1.2 Classification. Types of shipboard electric power to be supplied from the electric power system are classified as low voltage as follows:

Type I - Type I power is 440 or 115 volts (V), 60 hertz (Hz) ungrounded and is the standard shipboard electric power source. Type I power is used unless a deviation is granted (see 4.4)

Type II - Type II power is 440 or 115 V, 400 Hz ungrounded and has only limited application. Use of Type II power requires the submittal and approval of a deviation request (see 4.4).

Type III - Type III power is 440 or 115 V, 400 Hz ungrounded having tighter tolerances as compared to Type II. Type III power has restricted use and its use requires the submittal and approval of a deviation request (see 4.4).

1.2.1 Special power classification for avionic shops and aircraft servicing. Types of shipboard electric power supplied only for avionic shops and aircraft servicing are as follows:

Type I - Type I power is 115/200 V, 60 Hz, 3-phase, 4-wire, wye-grounded. This power is only provided for avionic shops.

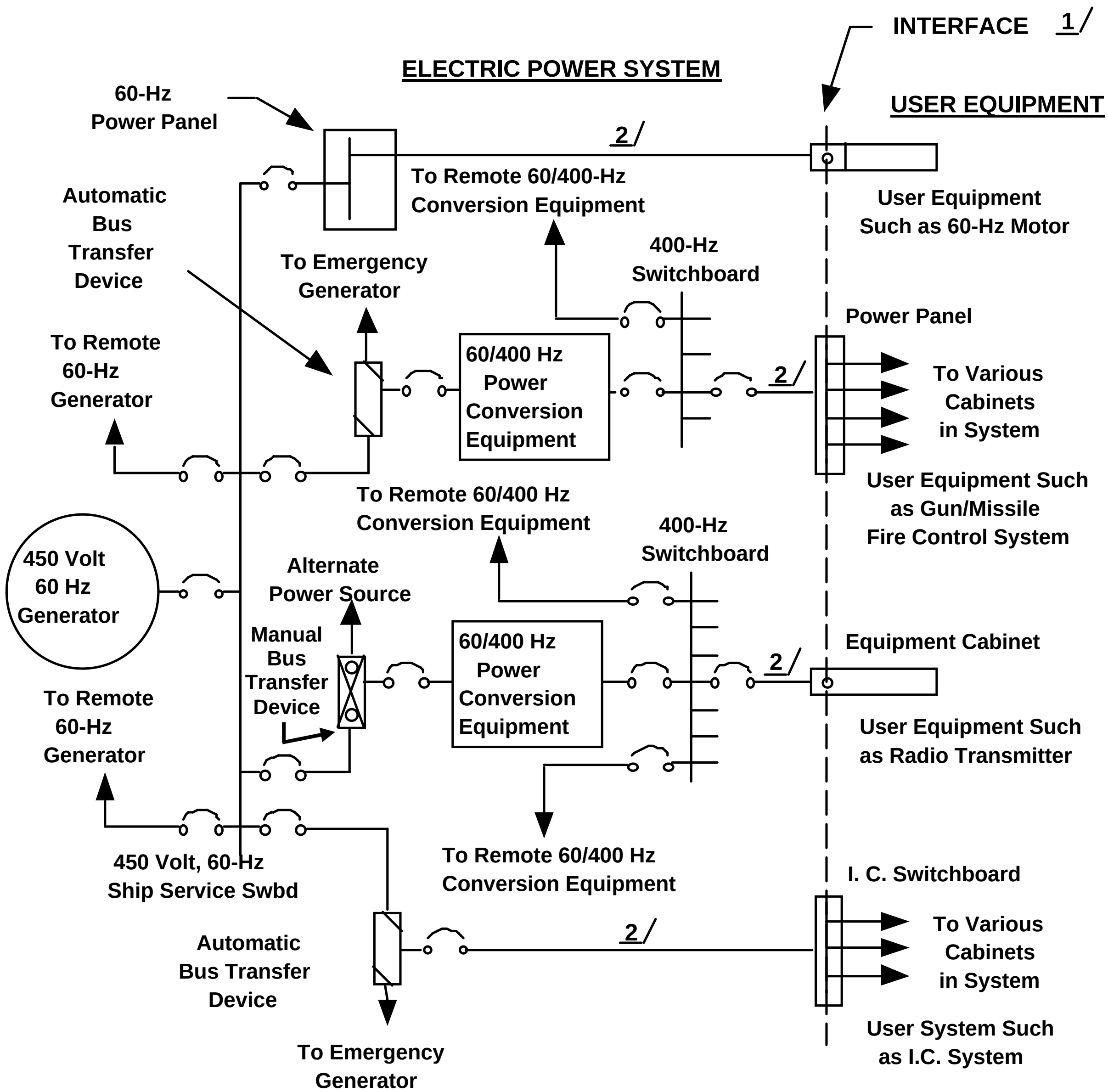
Type III - Type III power is 115/200 V, 400 Hz, 3-phase, 4-wire, wye-grounded. This power is only provided for avionic shops and for aircraft servicing.

1.2.2 Special power classification for NATO load equipment. Types of shipboard electric power supplied only for NATO load equipment are as follows:

Type I - Type I power is 230 V, 60 Hz, 3-phase, ungrounded or 230 V, 60 Hz, single-phase, grounded or ungrounded. Its tolerances are the same as for Type I power as described in Table I except that the spike voltage will be at 1400 V peak.

1.2.3 Special non-standard power. For types of shipboard electric power supplied for specific industrial equipment such as washers, dryers, etc., see NAVSEA Drawings 7512881 for 120/208 Vrms loads and 7598285 for 120/240 Vrms loads. Non-standard power should comply with Type I tolerances. See 5.2.4.1 NOTE for Human Body Leakage current voltage and frequency limits.

1.3 Electrical interface. The basic characteristic and constraint categories concerned with this interface are shown symbolically on Figure 1. This interface is a location between the electric power system and the user equipment. The interface is at the junction where the cable designations change from power or lighting designations, such as P, EP, PP, L, EL, or SF, to other designations or where no cable designation changes are made at the user equipment electric power input terminals. Functionally, the interface is the location wherein the electric power system characteristics (see 5.1) and the user equipment constraints (see 5.2) apply.



NOTES:

Typical Power System Characteristics: Voltage, Frequency, and Emergency Condition
Typical User Equipment Constraints: Type of Power, Power Factor, Power Interruption, Grounding, Load Unbalance, Pulsed Loads, Input Current Waveform, and Surge/Inrush Current
1/ Refer to 1.3 for a description of the interface.
2/ Cables with power/lighting designations.

FIGURE 1. Typical interface of electric power system and user equipment.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this standard, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-E-917 - Electric Power Equipment Basic Requirements

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-461 - Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

MIL-STD-1399 - Interface Standard for Shipboard Systems

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-2036 - Preparation of Electronic Equipment Specifications

(Copies of these documents are available online at http://assist.daps.dla.mil/quicksearch/ or http://assist.daps.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

NAVAL SEA SYSTEMS COMMAND (NAVSEA) DRAWINGS

7512881 - Standard Drawing Typical for Non-standard Power Distribution System 120/208 Vrms, with Grounded Neutral

7598285 - Standard Drawing Typical for Non-standard Power Distribution System 240/120 Vrms

(Copies of these documents are available from the Norfolk Naval Shipyard, Attn: Code 276, Portsmouth, VA 23709.)

NAVAL SHIP'S TECHNICAL MANUAL

NSTM Chapter 300 - Electric Plant - General

(Copies of this document are available online at http://nvl.nist.gov/ or from the NIST Weights and Measures Division, Laws and Metric Group, 100 Bureau Drive, Stop 2600, Gaithersburg, MD 20899-2600.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the 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.

3. DEFINITIONS

3.1 Electric power system. The electric power system is the electric power generation and distribution system (excluding electric propulsion systems) including generation, cables, switchboards, switches, protective devices, converters, transformers, and regulators up to the user equipment interface.

3.1.1 Electrical interface. The interface is the boundary between the electric power system and the user equipment where the electric power system characteristics and the user equipment compatibility requirements apply.

3.2 Electric power system ground. Ground is a plane or surface used by the electric power system as a common reference to establish zero potential. Usually, this surface is the metallic hull of the ship. On a nonmetallic hull ship, a special ground system is installed for this purpose.

3.2.1 Ungrounded electric power system. An ungrounded electric power system is a system that is intentionally not connected to the metal structure or the grounding system of the ship, except for test purposes. An ungrounded electric power system can continue to perform normally if one line conductor becomes solidly grounded. However, an ungrounded system may be subject to over-voltages greater than five times nominal voltage as a result of an inductive arcing ground between one line and ground.

3.2.2 High resistance-grounded electric power system. A high-resistance grounded electric power system is a system that employs an intentional high resistance between the electric system neutral and ground. High-resistance grounding provides the same advantages of ungrounded systems (i.e., the system can continue to perform normally with one line grounded) yet limits the severe transitory over-voltages associated with ungrounded systems.

3.2.3 Solidly-grounded electric power system. A solidly-grounded electric power system is a system in which at least one conductor or point (usually the neutral point of the transformer or generator winding) is intentionally and effectively connected to system ground. A single ground fault from one line to ground will produce high fault current that should cause selective tripping of protective circuit breakers interrupting power service continuity.

3.3 Frequency. Units are in Hertz (Hz).

3.3.1 Nominal frequency. Nominal frequency ($f_{nominal}$) is the designated frequency in Hz.

3.3.2 Frequency tolerance. Frequency tolerance is the maximum permitted departure from nominal frequency during normal operation, excluding transients and modulation. This includes variations such as those caused by load changes, the environment (temperature, humidity, vibration, inclination), and drift. Tolerances are expressed in percentage of nominal frequency.

3.3.3 Frequency modulation. Frequency modulation is the permitted periodic variation in frequency during normal operation, calculated by Equation 1 and shown in Figure 2. For purposes of definition, the periodicity of frequency modulation should be considered as greater than 1 cycle but not exceeding 10 seconds.

$$\text{Frequency modulation (percent)} = \left(\frac{f_{maximum} - f_{minimum}}{2 \times f_{nominal}}\right) x100$$

EQUATION 1

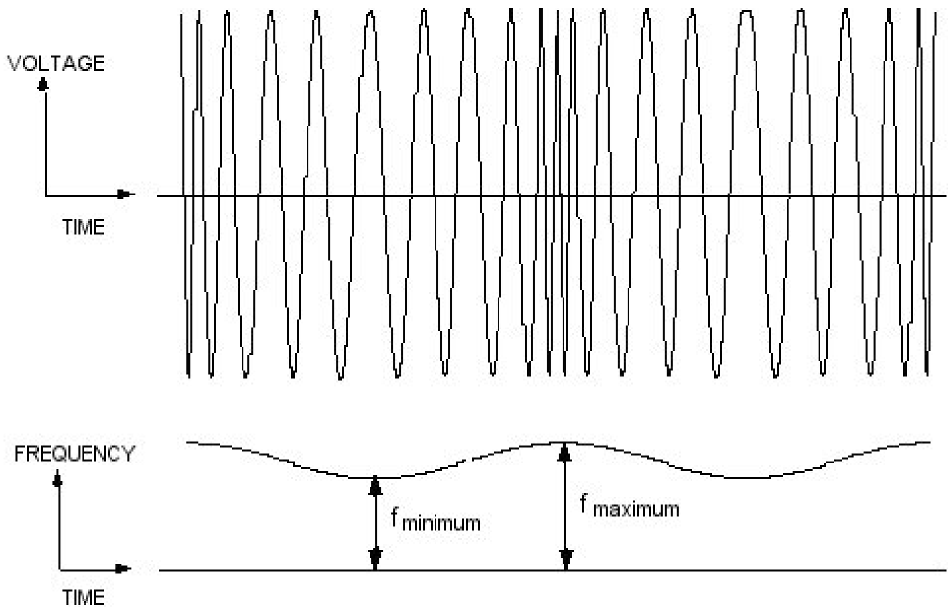


FIGURE 2. Frequency modulation.

3.3.4 Frequency transients. A frequency transient is a sudden change in frequency that goes outside the frequency tolerance limits and returns to and remains within these limits within a specified recovery time (longer than 1 ms) after the initiation of the disturbance.

3.3.4.1 Frequency transient tolerance. Frequency transient tolerance is the maximum permitted departure from nominal user frequency during transient conditions. The frequency transient tolerance is in addition to the frequency tolerance limits.

3.3.4.2 Frequency transient recovery time. Frequency transient recovery time is the time elapsed from the instant when the frequency first goes outside the frequency tolerance limits until the instant when the frequency recovers and remains within the frequency tolerance limits.

3.4 Voltage. Units are in Volts (V). Unless otherwise specified, voltages in this standard are root-mean-square (rms) values. Tolerances are expressed in percent of the nominal user voltage.

3.4.1 Nominal user voltage. Nominal user voltage ($V_{nominal}$) is the designated voltage at the interface.

3.4.2 User voltage tolerance. User voltage tolerance is the maximum permitted departure from nominal user voltage during normal operation, excluding transients and modulation. User voltage tolerance includes variations caused by load changes, the environment (temperature, humidity, vibration, inclination), and drift. Tolerances are expressed in percentage of nominal voltage. The average line-to-line voltage tolerance is calculated in Equation 2 and the line-to-line voltage tolerance is calculated in Equation 3. Voltages are either all rms or all peak (sinusoidal crest) values.

$$\text{Average line-to-line voltage tolerance (percent)} = \left(\frac{\text{Average voltage - Nominal user voltage}}{\text{Nominal user voltage}}\right)\times 100$$

Where:

The average voltage is the sum of the line-to-line voltages divided by the number of line-to-line voltages and the nominal user voltage is provided in Table I, item 7.

EQUATION 2

$$\text{Line-to-line voltage tolerance (percent)} = \left(\frac{\text{Line-to-line voltage} - \text{Nominal user voltage}}{\text{Nominal user voltage}}\right) \times 100$$

Where:

The line-to-line voltage is each line-to-line voltage and the nominal user voltage is provided in Table I, item 7.

EQUATION 3

3.4.3 Voltage unbalance (line-to-line). The line-to-line voltage unbalance is the maximum deviation of any of the three line-to-line voltages from the average voltage divided by the average voltage. Voltages are either all rms or all peak (sinusoidal crest) values as shown in Equation 4.

$$\text{Line-to-line voltage unbalance (percent)} = \left(\frac{\text{Maximum deviation from the average voltage}}{\text{Average voltage}}\right) \times 100$$

Where:

The average voltage is the sum of the line-to-line voltages divided by the number of line-to-line voltages.

EQUATION 4

3.4.4 Voltage modulation (amplitude). Voltage modulation is the periodic voltage variation (peak-to-valley) of a single line-to-line user voltage, calculated by Equation 5 and shown in Figure 3. The periodicity of voltage modulation should be considered to be longer than 1 cycle time at nominal frequency and less than 10 seconds. Voltages used in the following equation are either all rms or all peak (sinusoidal crest) values. $V_{nominal}$ is provided in Table I, item 7.

$$\text{Voltage modulation (percent)} = \left(\frac{V_{maximum} - V_{minimum}}{2 \times V_{nominal}}\right) \times 100$$

EQUATION 5

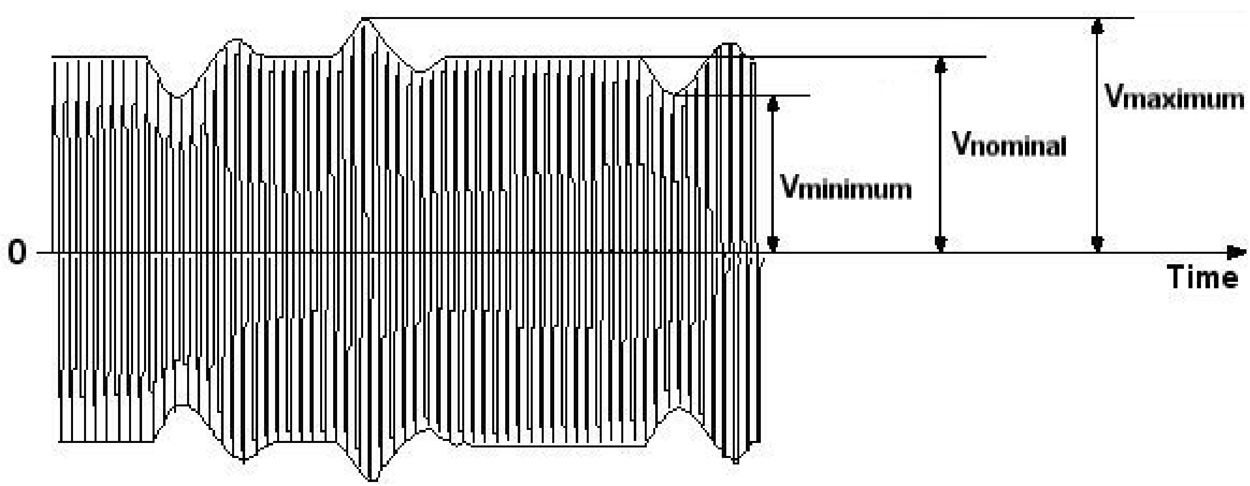


FIGURE 3. Voltage amplitude modulation.

3.4.5 Voltage transients. A voltage transient (excluding voltage spikes) is a sudden change in voltage that goes outside the user voltage tolerance limits and returns to and remains within these limits within a specified recovery time (longer than 1 ms) after the initiation of the disturbance.

3.4.5.1 Voltage transient tolerance. Voltage transient tolerance is the maximum permitted departure from nominal user voltage during transient conditions. The voltage transient tolerance is in addition to the user voltage tolerance limits.

3.4.5.2 Voltage transient recovery time. Voltage transient recovery time is the time elapsed from the instant when the voltage first goes outside the user voltage tolerance limit until the instant when the voltage recovers and remains within the user voltage tolerance limit. This is shown in Figure 4.

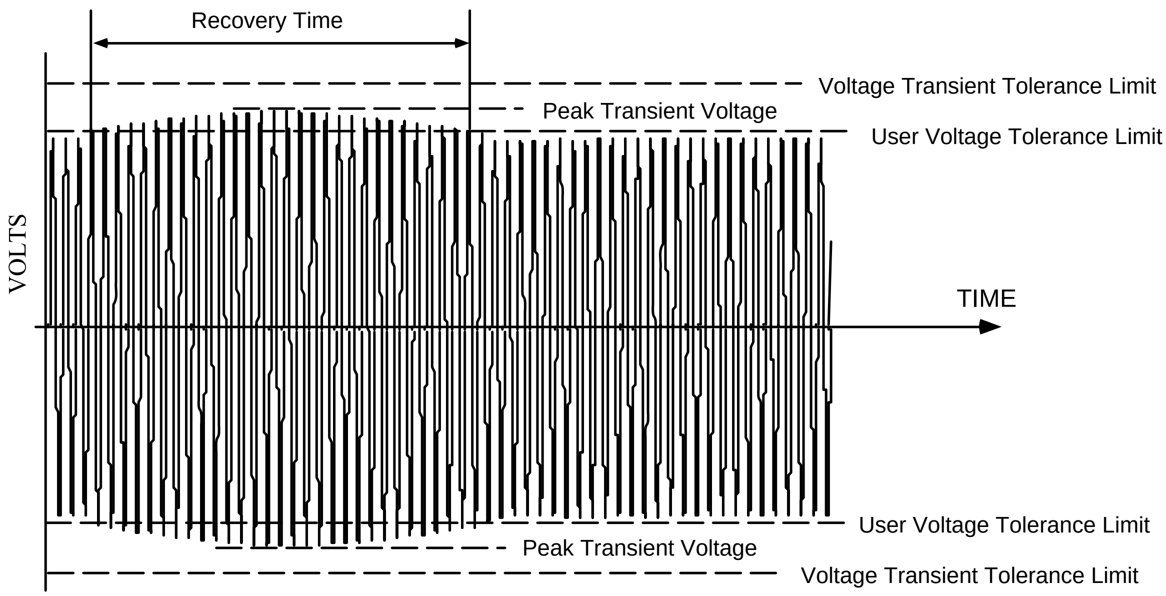


FIGURE 4. Voltage transient tolerance.

3.4.6 Voltage spike. A voltage spike is a voltage change or impulse of very short duration (less than 1 ms) represented in Figure 5. Voltage spikes in shipboard power systems are generally of an oscillatory nature and not unidirectional as those often used in testing. The impulse waveform shown in Figure 6 is the characteristic voltage spike used for test purposes.

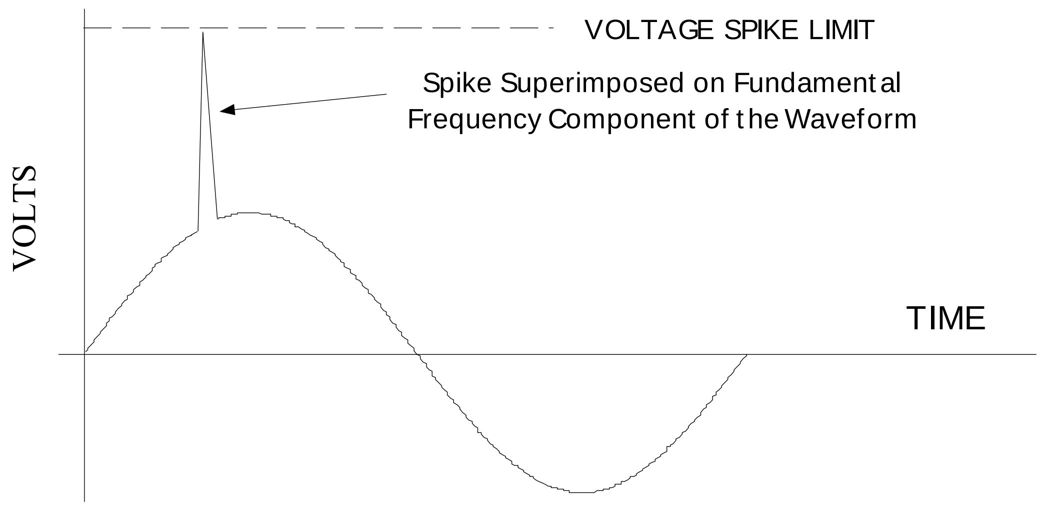
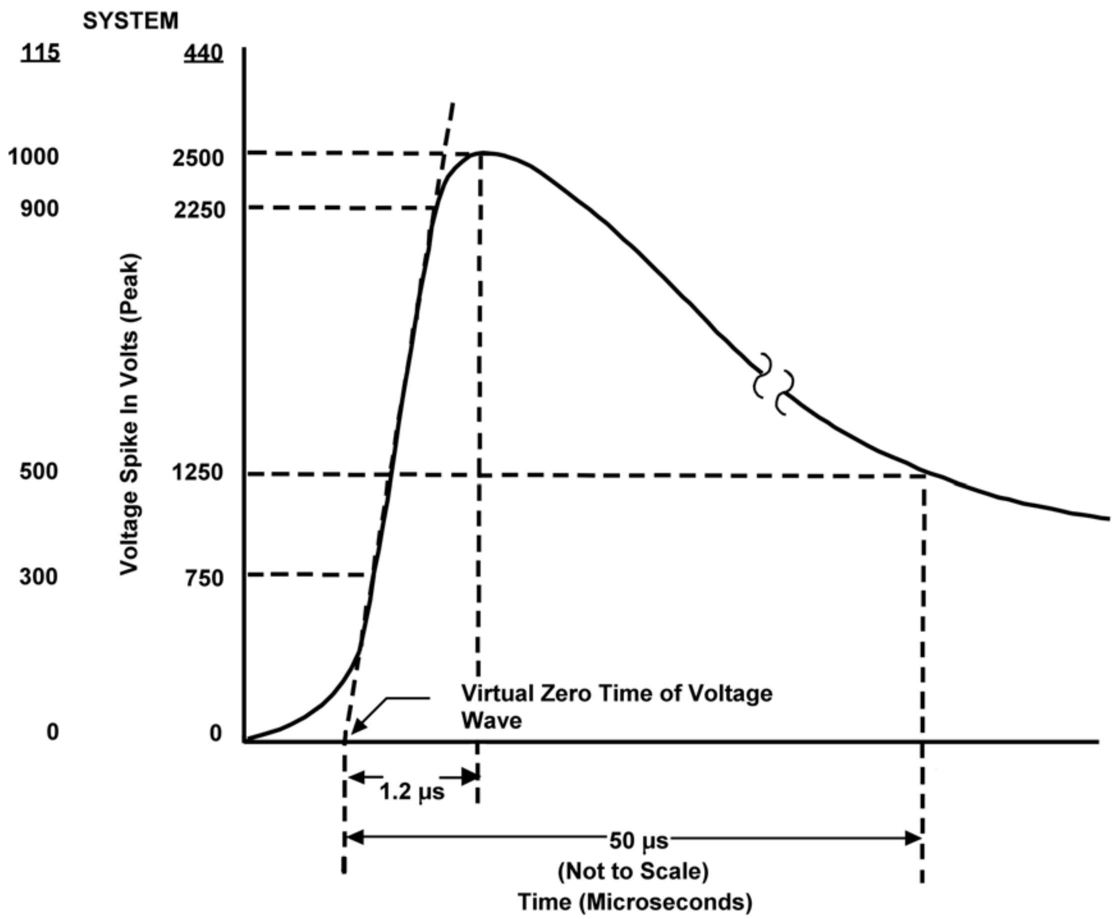


FIGURE 5. Voltage spike.



(NOTE: 2,500 V peak and 1,000 V peak spikes ride on the fundamental AC voltage waveform.)

FIGURE 6. Voltage spike impulse wave shape.

3.4.7 Voltage waveform. The voltage waveform is a voltage vs. time function.

3.4.7.1 Voltage single harmonic. A voltage single harmonic is a sinusoidal component of the voltage's periodic waveform having a frequency that is an integral multiple of the fundamental frequency.

3.4.7.2 Voltage single harmonic content. The voltage single harmonic content of a voltage wave is the ratio, in percentage, of the rms value of that harmonic to the rms value of the fundamental.

3.4.7.3 Voltage total harmonic distortion (THD). Total harmonic distortion of a voltage wave is the ratio in percentage of the rms value of the residue (after elimination of the fundamental) to the rms value of the fundamental, calculated by Equation 6.

$$\text{Voltage THD (percent)} = 100 \times \sqrt{\sum_{h \neq 1} \left(\frac{V_h}{V_{\text{fundamental}}} \right)^2}$$

Where:

V_h is the voltage of individual harmonics

$h \geq 2$

$V_{\text{fundamental}}$ is the voltage at 60 Hertz

EQUATION 6

3.4.7.4 Voltage deviation factor. The voltage deviation factor of the voltage waveform is the ratio (a/b) where "a" is the maximum deviation between corresponding ordinates of the waveform and of the equivalent sine wave and "b" is the maximum ordinate of the equivalent sine wave when the waveforms are superimposed in such a way that they make the maximum difference as small as possible. This is calculated by Equation 7 and shown in Figure 7. NOTE: The equivalent sine wave is defined as having the same frequency and the same rms voltage as the waveform being tested.

$$\text{Voltage deviation factor (percent)} = \left(\frac{\text{Maximum deviation}}{\text{Maximum ordinate of the equivalent sine wave}} \right) \times 100$$

EQUATION 7

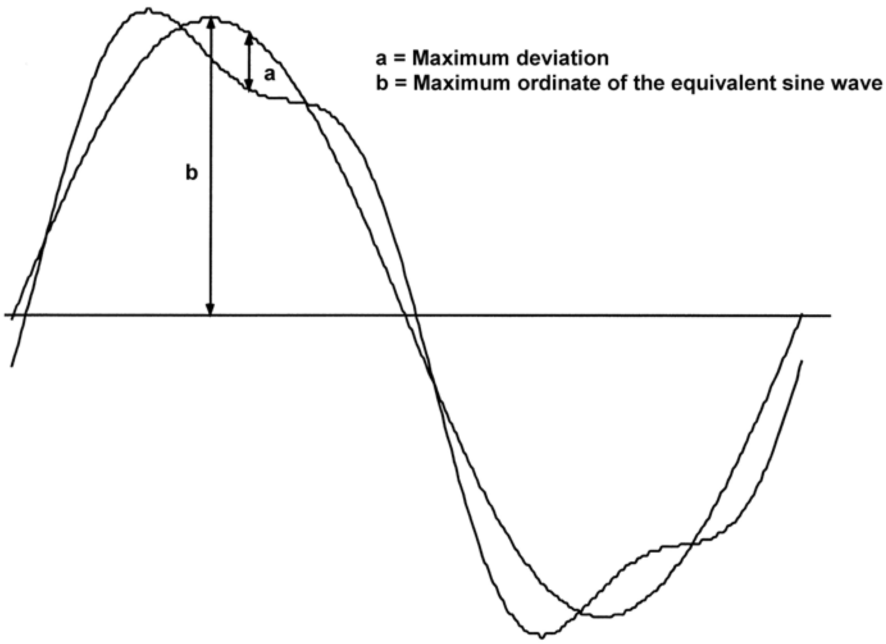


FIGURE 7. Voltage deviation factor variables.

3.5 Current. Units are in Amperes (A). Unless otherwise specified, currents in this standard are rms values.

3.5.1 Current unbalance. Current unbalance for three-phase loads is the ratio of the maximum line current magnitude minus the minimum line current magnitude to the average of the three line current magnitudes in amperes, shown in Equation 8. Currents used in the following equation are rms values.

$$\text{Current unbalance (percent)} = \left(\frac{I_{linemax} - I_{linemin}}{(I_A + I_B + I_C)/3}\right) \times 100$$

EQUATION 8

3.5.2 Current waveform. The current waveform is a current vs. time function.

3.5.2.1 Current single harmonic. A current single harmonic is a sinusoidal component of the current's periodic waveform having a frequency that is an integral multiple of the fundamental frequency.

3.5.2.2 Current single harmonic content. The current single harmonic content of a current waveform is the ratio, in percentage, of the rms value of that harmonic to the rms value of the fundamental.

3.5.3 Surge/inrush current. Surge current is a sudden change in line current to a user equipment that occurs during start-up or after a power interruption or as a result of a change to the operating mode. Typically, the surge current will rise to a maximum value in a few milliseconds (msec) and decay to rated value in several msec to several seconds.

3.6 Power factor (pf). Pf is the ratio of the real power in watts to the product of the rms voltage and rms current. For voltage waveforms with minimal distortion, pf can be approximated as the product of the displacement pf (dpf) and the distortion (μ). This is shown in Equation 9.

$$\mathrm{Pf} = \frac{\mathrm{P\,(watts)}}{\mathrm{Vrms\,Irms}} \approx \mu\ \mathrm{dpf}$$

EQUATION 9

3.6.1 Displacement power factor (dpf). The dpf is defined as the cosine of the angle difference between the fundamental frequency component of the input voltage and the fundamental frequency component of the current, shown in Equation 10. The dpf is the same as the pf in linear circuits with sinusoidal voltages and currents. The angle determines whether the pf is leading or lagging. A positive value of the angle means that the current lags the voltage (lagging pf, inductive load). A negative value of the angle means that the current leads the voltage (leading pf, capacitive load).

$$\mathrm{dpf} = \cos\left(\phi_V - \phi_I\right)$$

Where:

φ_V is the angle of the fundamental frequency component of the input voltage

φ_I is the angle of the fundamental frequency component of the current

EQUATION 10

3.6.2 Distortion component (μ) of power factor. The distortion component (μ) of power factor is the ratio of the rms magnitudes of the fundamental frequency current to the total current, shown in Equation 11.

$$\mu = \frac{I_{fundamental}}{I_{total}}$$

Where:

$I_{fundamental}$ is the rms value of the fundamental frequency current

I_{total} is the rms value of the total current

EQUATION 11

3.7 Power. Quantity that consists of real, reactive, and apparent power.

3.7.1 Real power. Real power, or average power, is defined as the product of the rms voltage and rms current multiplied by the power factor (pf). The unit of real power is the watt. Real power provides work over time.

3.7.2 Reactive power. Reactive power is defined as the product of the rms voltage and rms current multiplied by a reactive factor. The unit of reactive power is volt-ampere reactive (VAR). Reactive power provides no net energy transfer over time; the average reactive power is zero.

3.7.3 Apparent power. Apparent power is defined as the product of the rms voltage and the rms current. The unit of apparent power is volt-ampere (VA). Apparent power can be calculated as the square root of the sum of the squares of real and reactive power.

3.8 Pulse. A pulse is a brief excursion of power lasting longer than 1 cycle at nominal frequency and less than 10 seconds.

3.9 Pulsed load. A pulsed load may be user equipment, which demands frequent or regular repeated power input. A pulsed load is measured as the average power during the pulse interval minus the average power during the same interval immediately preceding the pulse. An example of a pulsed load is sonar or radar. A pulsed load can result in modulation in the system voltage amplitude and frequency.

3.10 Ramp load. A ramp load is a load that is applied to the electrical system as a smooth ramp or in steps (increments of the total load).

3.11 User equipment. User equipment is any system or equipment that uses electric power from the shipboard electric power system.

3.12 Emergency condition. An emergency condition is an unexpected occurrence of a serious nature that may result in electrical power system deviations as specified under emergency conditions. Emergency conditions include but are not limited to battle damage and malfunction/failure of equipment.

3.13 Limited-break power source. A limited-break power source is a power source provided by one or two or more independent power sources incorporating automatic means for detecting failure of the power source and for transferring the user equipment load to another power source within a specified time period.

3.14 No-break power source. A no-break power source is a device which maintains a continuous supply of electric power to connected equipment by supplying power from a separate source when utility power is not available.

4. GENERAL REQUIREMENTS

4.1 Interface requirements. The specific interface requirements and constraints established herein are mandatory and shall be adhered to regarding any aspect of shipboard electrical power systems or user equipment designs to which these requirements and constraints apply, including systems and equipment design, production, and installation (see MIL-STD-1399). MIL-HDBK-2036 may be used as a guide for tailoring of requirements.

4.2 Conformance test requirements. Requirements and tests (see 5.3) to ensure conformance of equipment to the interface requirements and constraints incorporated in this standard shall be included in the electric power system and user equipment specifications. Conformance of requirements (see 5.3) shall be verified by test.

4.3 User equipment. User equipment shall operate from a power system having the characteristics of Table I and shall be designed within these constraints in order to reduce adverse effects of the user equipment on the electric power system. Test methods are included for verification of compatibility. User equipment to be installed on ships built to superseded versions of this standard shall meet the most stringent demands of the applicable version.

4.4 Deviations. The power interfaces in this standard are based on a traditional AC electric power system. To meet the intent of this section for non-traditional electric power systems, deviation of requirements will be considered. The deviation provisions in MIL-STD-1399 shall be adhered to during the early development stage of user equipment, as specified (see 6.2 and 6.5).

5. DETAILED REQUIREMENTS

5.1 Electric power system characteristics. The shipboard electric power system serves a variety of user equipment such as aircraft elevators, air conditioners, communication equipment, weapon systems, and computers. Electric power is centrally generated and distributed throughout the ship from the switchboard to power panels and finally to the user equipment served. Ship design requires that conversion equipment be minimized and that most equipment served be designed to operate from the Type I, 60 Hz power system. Performance of the ship can best be served by minimizing the requirement for Types II or III, 400 Hz power. Characteristics of shipboard electric power systems at the interface shall be as specified in Table I. For 115/200 V, 4-wire grounded systems as specified in 5.1.6.2 (c) and (d), the characteristics apply to line to neutral power unless the parameter is inappropriate; for example, line balance would not apply. Type II or III power is provided by deviation only (see 4.4 and 6.5). Type I, 60 Hz power shall be used for new user equipment development unless a deviation is granted. Frequency will not decrease to 0 (minus 100 percent) without a decrease in voltage. Figure 8, 5.1.3.3, and 5.1.3.4 shall apply.

TABLE I. Characteristics of shipboard electric power systems.
(NOTE: Characteristic percentages are defined in Section 3.)

Characteristics	**Type I**	**Type II**	**Type III**
Frequency			
1. Nominal frequency	60 Hz	400 Hz	400 Hz
2. Frequency tolerance	±3% (±5% for submarines)	±5%	±0.5%
3. Frequency modulation	0.5%	0.5%	0.5%
4. Frequency transient tolerance	±4%	±4%	±1%
5. Worst case frequency excursion from nominal resulting from items 2, 3, and 4 combined, except under emergency conditions	±5.5%	±6.5%	±1.5%
6. Recovery time from items 4 or 5	2 seconds	2 seconds	0.25 second
Voltage			
7. Nominal user voltage	440, 115, 115/200 Vrms	440, 115 Vrms	440, 115, 115/200 Vrms
8. Line-to-line voltage unbalance	3% (0.5% for 440 Vrms, 1% for 115 Vrms for submarines)	3%	2%
9. User voltage tolerance			
a. Average line-to-line voltage from nominal	±5%	±5%	±2%
b. Line-to-line voltage from nominal, including items 8 and 9.a	±7%	±7%	±3%
10. Voltage modulation	2%	2%	1%
11. Maximum departure voltage from nominal resulting from items 8, 9a, 9b, and 10 combined, except under transient or emergency conditions	±8%	±8%	±4%
12. Voltage transient tolerance	±16%	±16%	±5%
13. Worst case voltage excursion from nominal resulting from items 8, 9.a, 9.b, 10 and 12 combined, except under emergency conditions	±20%	±20%	±5.5%
14. Recovery time from item 12 or item 13	2 seconds	2 seconds	0.25 second
15. Voltage spike (± peak value)	2.5 kV (440 Vrms sys) 1.0 kV (115 Vrms sys)	2.5 kV (440 Vrms sys) 1.0 kV (115 Vrms sys)	2.5 kV (440 Vrms sys) 1.0 kV (115 Vrms sys)
Waveform (voltage)			
16. Maximum total harmonic distortion	5%	5%	3%
17. Maximum single harmonic	3%	3%	2%
18. Maximum deviation factor	5% (3% for submarines)	5%	5%
Emergency conditions			
19. Frequency excursion	-100% to +12%	-100% to +12%	-100% to +12%
20. Duration of frequency excursion	2 minutes	2 minutes	2 minutes
21. Voltage excursion	-100% to +35%	-100% to +35%	-100% to +35%
22. Duration of voltage excursion			
a. Upper limit (+35%)	2 minutes	0.17 second	0.17 second
b. Lower limit (-100%)	2 minutes	2 minutes	2 minutes

5.1.1 Types of power. Types of power are as follows:

5.1.1.1 Type I, 60 Hz power. The ship service electrical power distribution system supplied by the ship's generators is 440 Vrms, 60 Hz, three-phase, ungrounded. Power for the ship's lighting distribution system and other user equipment such as electronic equipment, supplied from the ship service power distribution system through transformers, is 115 Vrms, 60 Hz, three-phase, ungrounded. Single-phase power is available from both the 440 Vrms and the 115 Vrms systems. The ship service power and lighting distribution systems are labeled as Type I. Type I, 230 Vrms, 60 Hz, single or three-phase, grounded or ungrounded power can be made available for NATO load equipment upon special request. See 1.2.1, 1.2.2, and 1.2.3 for special power types.

5.1.1.2 Types II and III, 400 Hz power. The ship service power supplied by 400 Hz motor-generator sets or solid-state converters is 440 Vrms, three-phase, 400 Hz ungrounded. The 400 Hz power is of two kinds, designated as Types II and III. Subject to the approval of a deviation request, the use of Type II is preferred over Type III, but, if more precise characteristics are required, Type III power may be supplied. Type III, 115/200 Vrms, 400 Hz, three-phase, four-wire, grounded wye power is available for avionics shops and for aircraft servicing.

5.1.2 System grounding. Electric power systems shall be ungrounded, except as specified in 5.1.6.2 (c) and (d) and 5.2.4. Momentary intentional grounding is permitted for the operation of ground detection equipment. High resistance grounding may be installed only with NAVSEA approval. Line-to-ground current of up to 20 amperes may exist in an electric power system as a result of capacitive coupling of cables and equipment filters connected to ground.

5.1.2.1 Ungrounded system. Under ungrounded system conditions, an ungrounded electric power system shall continue to perform normally if one line conductor becomes solidly grounded.

5.1.2.2 Grounded system. A single ground fault from one line to ground will produce high fault current that shall trip protective circuit breakers, isolating the fault.

5.1.2.3 High resistance-grounded system. This system employs an intentional resistance between the electric system neutral and ground. The resistance shunts the system capacitance-to-ground, reducing possible over-voltages-to-ground. The resistance reduces line-to-ground fault current so the electric power system shall continue to perform normally if one line conductor becomes solidly grounded; the ground is indicated by the reduced fault current.

5.1.3 Power interruption. Power interruptions may range from less than 1 msec to several minutes. The interruptions can occur as a result of an equipment casualty, training exercise, or operator error. In order to maintain reliability and continuity during the diverse operating conditions such as anchor, cruising, functional, and emergency conditions, some loads are provided with a limited-break power source where possible. The extent to which this can be done will vary with the ship design, electric plant capacity, and the specific user equipment. In some instances, user systems and equipment are not provided with a limited-break power source because of the need to control the power-up cycle after the interruption. In other instances, the capacity of the ship service or emergency generators may limit the use of limited-break power sources. In those instances, user equipments will be provided two sources of power selectable by means of a manual transfer switch.

5.1.3.1 Limited-break power source. A limited-break power source is accomplished by means of a normal feeder from one ship service switchboard and either an alternate feeder from another ship service switchboard or an emergency switchboard by means of a bus transfer switch. A time delay may be required between the loss of the normal power source and switching to the alternate power source to avoid excessive transient currents caused by residual voltage. In the case of switching from a normal to emergency power source, an additional time delay is experienced to automatically start the emergency generator on standby. The time delays result in a transfer time from one power source to another of 0.008 seconds (solid-state switch) or 0.04 seconds (electromechanical switch) to several minutes.

5.1.3.2 No-break supply (uninterruptible power supply). No-break supply is accomplished by a power supply provided by one or more independent power sources for which the change over time is zero and the supply characteristics are continuously held within specified limits. In a special case, a no-break supply may be specified to have a limited time duration for the alternative source. A no-break power supply is not normally provided by the shipboard electric power system. If a no-break power supply is required, it shall be provided as part of the user equipment, but shall be subject to specific functional requirements established by NAVSEA.

5.1.3.3 Power interruption, Type I, 60 Hz electric power system. An electric power interruption can occur on Type I, 60 Hz electric power system as a result of the loss of prime mover, equipment failures, or by the operation of switching equipment. The interruption can occur during normal operations when no damage has occurred such as during training exercises or during mechanical or electric power system tests. Figure 8 illustrates the voltage and frequency decay characteristics of a steam driven generator set on loss of prime mover. The voltage may start to decay when the frequency decays to about 40 Hz. The frequency decays to 40 Hz in approximately 5 to 20 seconds after the loss of the prime mover, depending on the initial load and the inertia of the generator set. Under a power interruption condition, the voltage may not reduce to zero for several minutes. The voltage and frequency of generators driven by gas turbine and diesel prime movers will fall off faster than that of the steam prime mover.

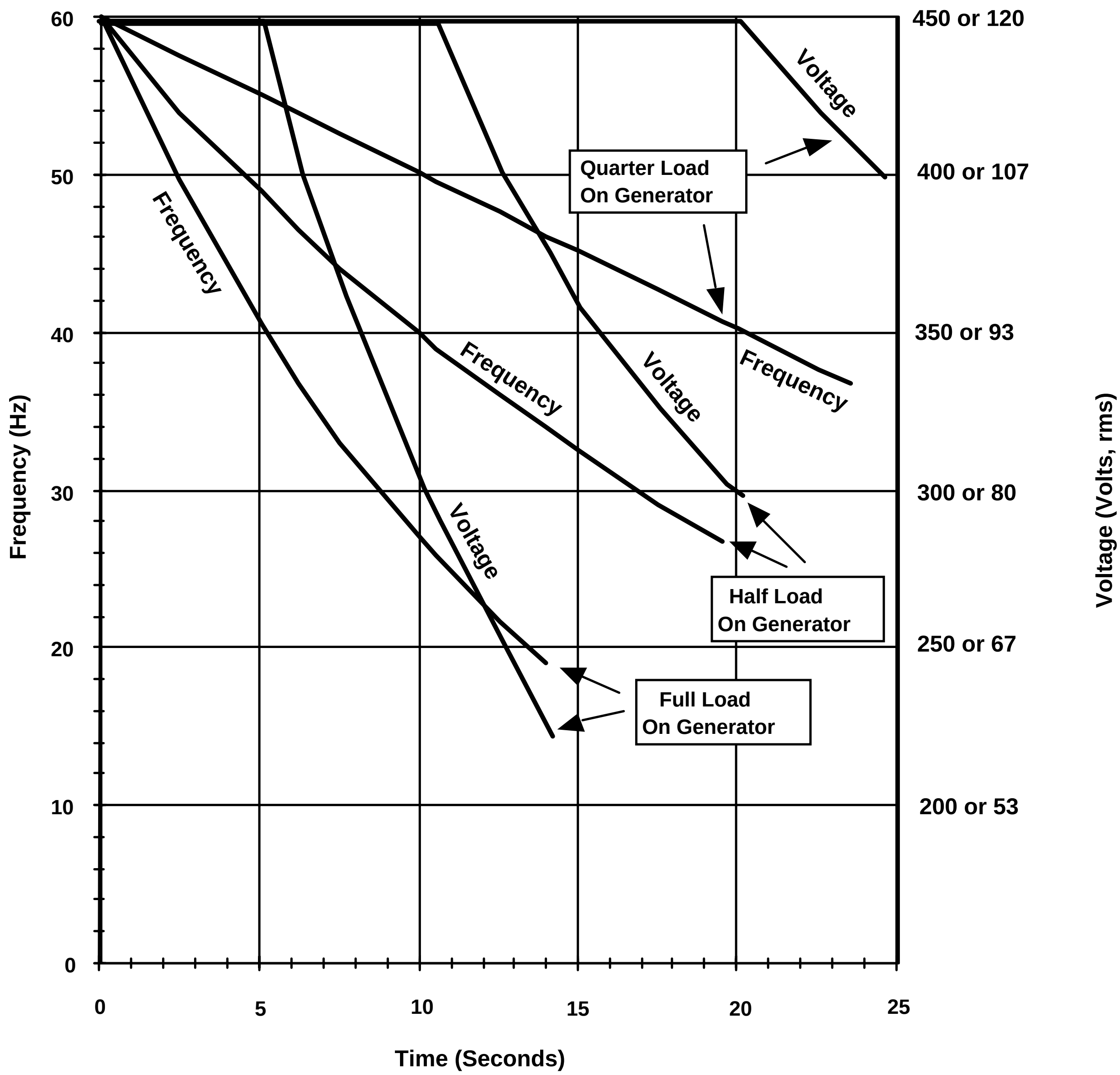


FIGURE 8. Voltage and frequency decay characteristics on loss of prime mover for typical steam turbine driven generator set, Type I, 60-Hz electric power system.

5.1.3.4 Power interruption, Types II and III electric power system. Loss of input power to 60/400 Hz motor generator (MG) sets will activate control circuits provided with MG sets which trip the MG circuit breaker. This interrupts power to 400 Hz loads in a few milliseconds. Upon loss of 60 Hz power to solid-state frequency changers, the 400 Hz power is interrupted within 2 msec by controls in the frequency changer. Voltage and frequency monitors that are provided separately from conversion equipment controls, trip the MG 400 Hz output circuit breaker when the output voltage or frequency reach those values specified in 5.1.5.2 or 5.1.5.3 as applicable to the type power provided.

5.1.4 Phase sequence. Standard phase sequence for three-phase AC systems in the U.S. Navy is in the following order: AB, BC, and CA. For grounded systems, the phase sequence is AN, BN, CN.

5.1.4.1 Phase angular relations. The ungrounded three-phase source shall have an angular relationship of 120 degrees between phases under balanced load conditions. If the source is a grounded, 4-wire system (with neutral), the angular displacement between phases shall not exceed 120 degrees ±1 degree under balanced load conditions.

5.1.5 Electric power system protection. Protection is provided for the electric power system but not for user equipment.

5.1.5.1 Type I, 60 Hz electric power system. The electric power system protection shall be a circuit breaker and/or fuse that are sized to provide overcurrent and fault current protection.

5.1.5.2 Type II, 400 Hz electric power system protection. For the 400 Hz electric power system, protective devices (separate from protection devices that may be provided to integral conversion equipment) are provided to interrupt the Type II electric power system within 100 to 170 msec if the voltage or frequency excursions exceed the limits set forth below:

a. Overvoltage: 120 to 130 percent of nominal voltage in any phase measured line-to-line.

b. Undervoltage: 70 to 80 percent of nominal voltage in any phase measured line-to-line.

c. Overfrequency: 425 to 435 Hz.

d. Underfrequency: 365 to 375 Hz.

5.1.5.3 Type III, 400 Hz electric power system protection. For the 400 Hz electric power system, protective devices (separate from protection devices that may be provided to integral conversion equipment) are provided to interrupt the Type III electric power system within 100 to 170 msec if the voltage or frequency excursions exceed the limits set forth below:

a. Overvoltage: 110 to 120 percent of nominal voltage in any phase measured line-to-line on delta-connected systems and line-to-neutral on 115 to 200 Vrms wye-connected systems.

b. Undervoltage: 84 to 90 percent of nominal voltage in any phase measured line-to-line on delta-connected systems and line-to-neutral on 115 to 200 Vrms wye-connected systems.

c. Overfrequency: Above 415 to 425 Hz.

d. Underfrequency: Below 375 to 385 Hz (surface ships).

5.1.5.4 Conditions not protected against. The electric power system protection shall not interrupt the electric power to the user equipment under the following conditions:

a. High voltage excursions of very short duration (voltage spike) (see Figures 5 and 6).

b. The momentary interruption and restoration of power of less than 100 ms.

c. 500 VDC insulation resistance tests performed using megohmmeters. (Surface ships)

d. Active ground detector tests (submarines) where 150 VDC is added to the 440 Vrms waveform and 50 VDC is added to the 115 Vrms waveform. NOTE: Legacy systems may utilize 500 VDC added to the 440 Vrms waveform and 150 VDC added to the 115 Vrms waveform.

5.1.6 Electric power system parameters. Ensure power system parameters shall be as specified in 5.1.6.1 through 5.1.6.3.

5.1.6.1 System frequency. System frequency is 60 Hz. Where there are overriding design features demanding a different frequency, deviations from this requirement are subject to the requirements of 4.4 and 6.5.

5.1.6.1.1 Type I, 60 Hz frequency transients. Figure 9 illustrates the Type I, 60 Hz frequency tolerance and worst case frequency excursion envelope limits specified in Table I. The time to reach the transient minimum or maximum varies from 0.1 to 1.0 seconds after initiation of the disturbance. The frequency shall recover to the frequency tolerance band within 2 seconds.

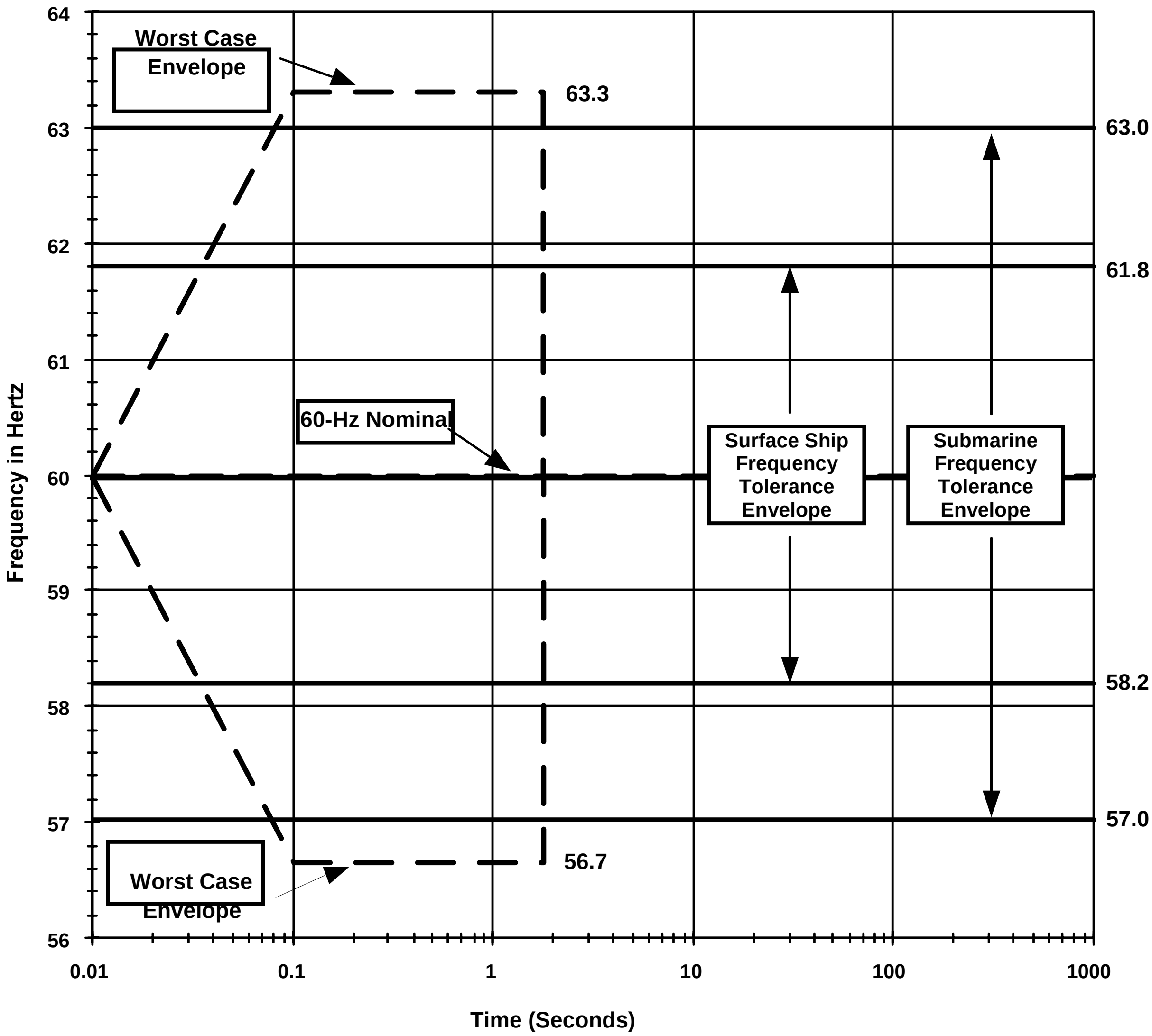


FIGURE 9. Type I worst case and frequency tolerance envelopes.

5.1.6.1.2 Type II, 400 Hz frequency transients. Figure 10 illustrates the Type II, 400 Hz frequency tolerance and worst-case frequency excursion envelope limits specified in Table I. The time to reach the transient minimum or maximum varies from 0.05 to 0.1 seconds after initiation of the disturbance. The frequency will recover to the frequency tolerance band within 2 seconds.

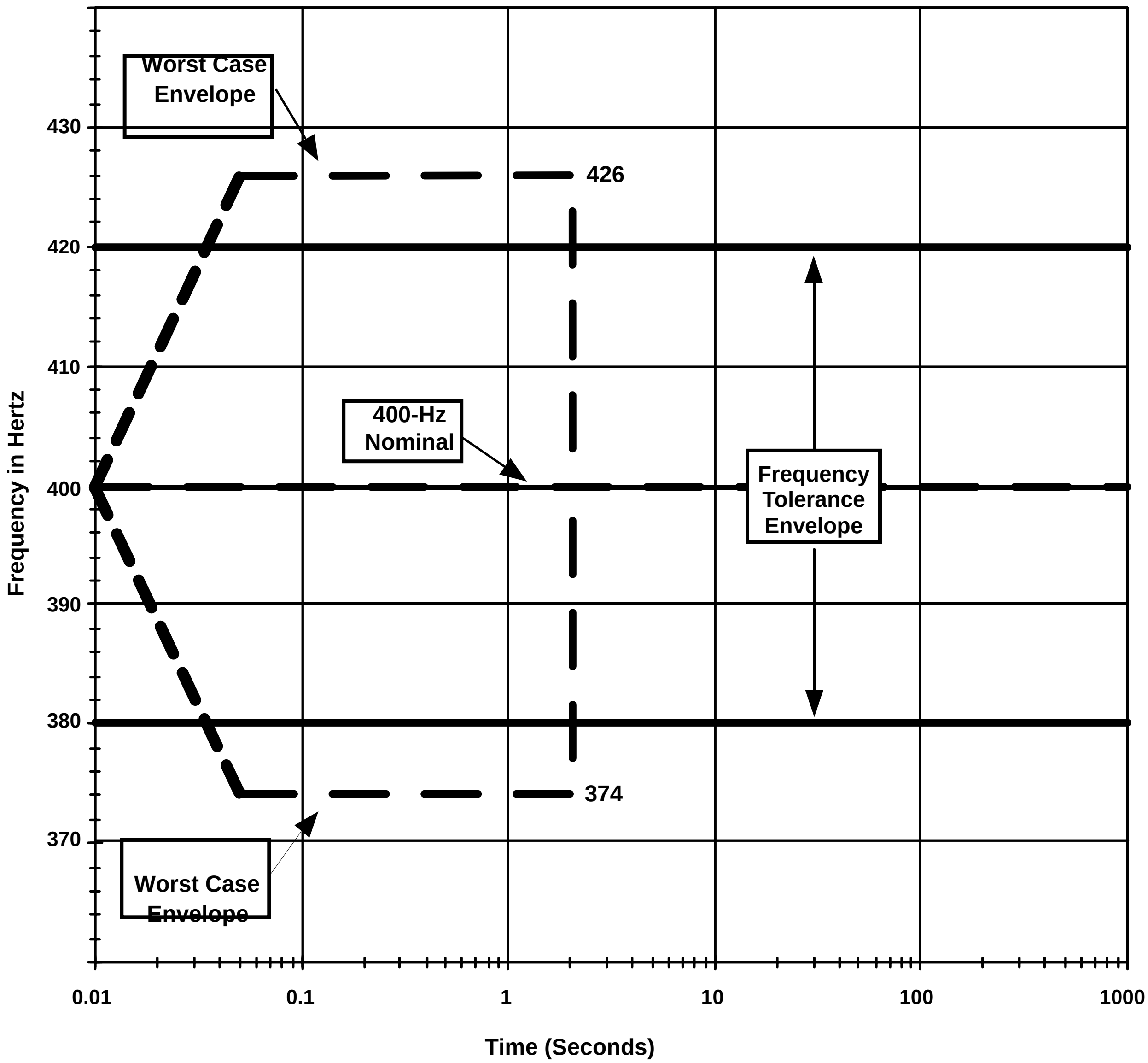


FIGURE 10. Type II worst case and frequency tolerance envelopes.

5.1.6.1.3 Type III, 400 Hz frequency transients. Figure 11 illustrates the Type III, 400 Hz frequency tolerance and worst-case frequency excursion envelope limits specified in Table I. The time to reach the transient minimum or maximum varies from 0.05 to 0.1 seconds after initiation of the disturbance. The frequency will recover to the frequency tolerance band within 0.25 seconds.

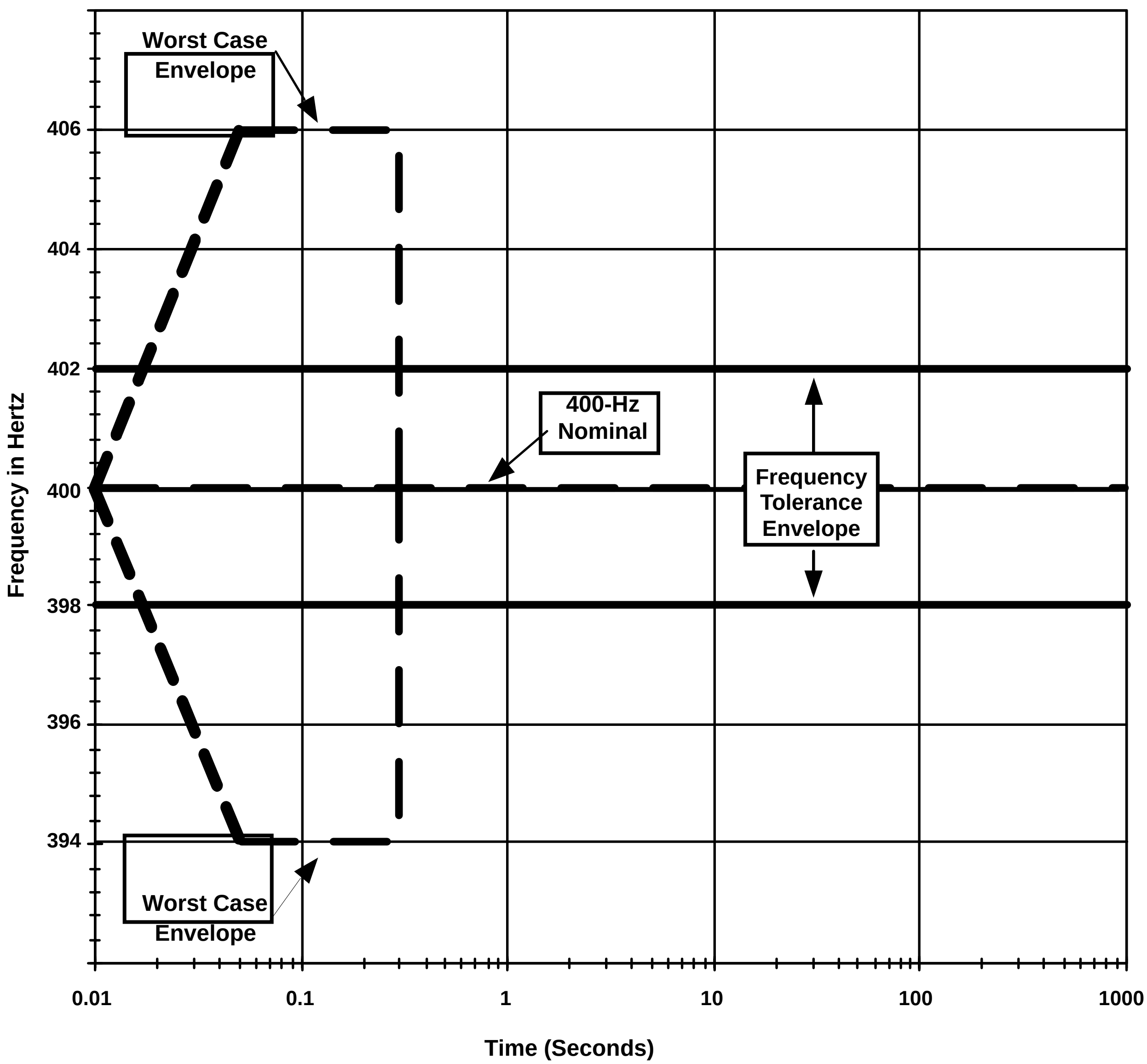


FIGURE 11. Type III worst case and frequency tolerance envelopes.

5.1.6.2 System voltage. System voltages are as follows (see 5.2.2):

a. 440 Vrms, 3-phase (ungrounded).

b. 115 Vrms, 3-phase (ungrounded).

c. Special service, 115/200 Vrms, 3-phase, 4-wire, grounded neutral, 400 Hz power is provided for servicing aircraft in hangars and on flight decks, and to avionics shops.

d. Special service, 115/200 Vrms, 3-phase, 4-wire, grounded neutral, 60 Hz power is provided for avionic shops.

e. Special service, 230 Vrms, 60 Hz, 3-phase, ungrounded or 230 Vrms, 60 Hz, single-phase, grounded or ungrounded. This power is provided upon request only for NATO load equipment.

f. Special service, 120/208 Vrms, 60 Hz, 3-phase, 4-wire, grounded neutral or 240/120 Vrms, 60 Hz, single-phase, grounded neutral. These special distribution system voltages shall be in accordance with NAVSEA Standard Drawing 7512881 and NAVSEA Standard Drawing 7598285, respectively.

5.1.6.2.1 Type I, 60 Hz and Type II, 400 Hz power voltage transient. Figure 12 illustrates the 440 Vrms Type I, 60 Hz and Type II, 400 Hz voltage transient and user voltage tolerance envelope specified in Table I. Figure 13 illustrates the 115 Vrms, Type I, 60 Hz and Type II, 400 Hz, worst case voltage excursion and user voltage tolerance envelope specified in Table I. Voltage transients of 10 percent or less may occur several times an hour, and voltage transients of 10 to 16 percent may occur several times a day (percentages based on nominal user voltage). The time to reach the transient maximum may vary from 0.001 to 0.03 seconds, or to reach the transient minimum may vary from 0.001 to 0.06 seconds on Types I and II power systems, depending on the rating of the generator and the type regulator and excitation system employed. The sudden application of user equipment to the Type I or II electric power system may cause the voltage to decrease to the transient voltage minimum value within 0.001 to 0.06 seconds. The voltage may then increase to a maximum value that is above the nominal voltage by an amount equal to ⅓ to ⅔ of the minimum transient voltage drop at a rate equal to 20 to 75 percent of the nominal voltage per second. Recovery to within the user voltage tolerance envelope will occur within 2 seconds. The sudden removal of user equipment from the electric power system may cause the voltage to increase to the transient voltage maximum within 0.001 to 0.03 seconds. The voltage may then decrease to a minimum value that is below the nominal voltage by an amount equal to ⅓ to ⅔ of the maximum transient voltage rise at a rate equal to 20 to 75 percent of the nominal voltage per second. Recovery to within the user voltage tolerance envelope will occur within 2 seconds.

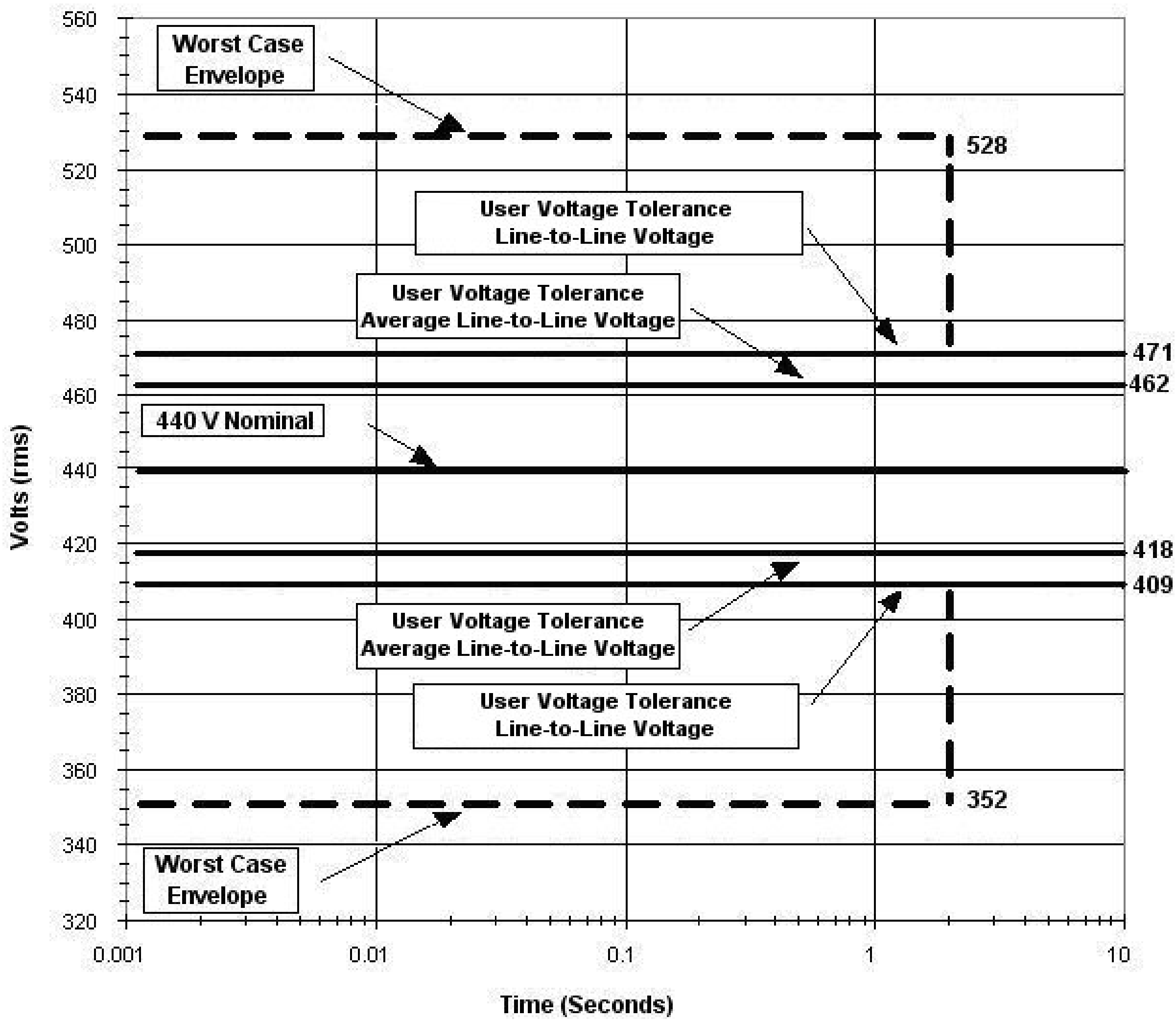


FIGURE 12. Types I and II, 440 Vrms power - worst case and user voltage tolerance envelopes.

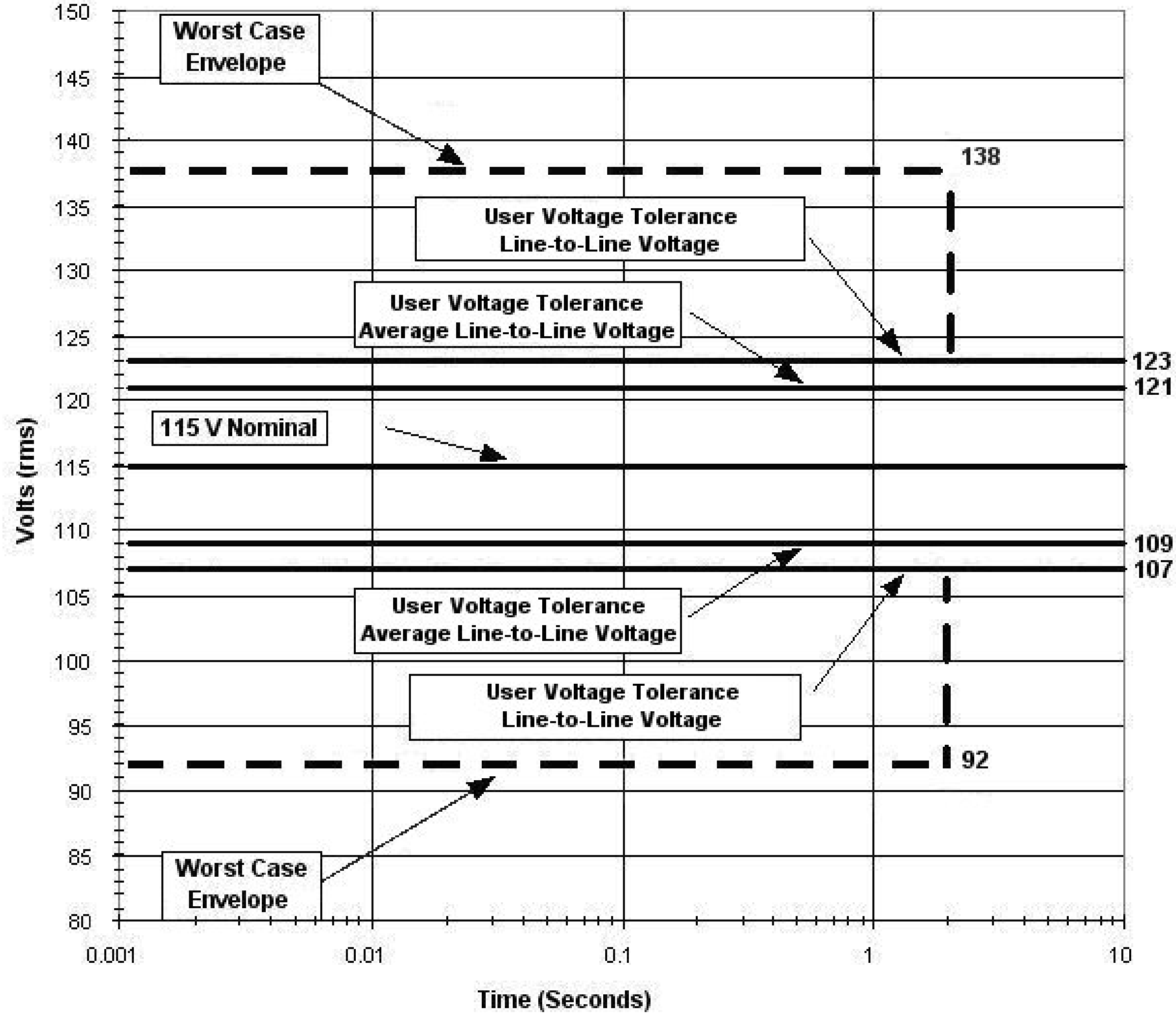


FIGURE 13. Types I and II, 115 Vrms power - worst case and user voltage tolerance envelopes.

5.1.6.2.2 Type III, 400 Hz power transient voltage. Figure 14 illustrates the 440 Vrms, Type III, 400 Hz worst case voltage excursion and user voltage tolerance envelope specified in Table I. Figure 15 illustrates the 115 Vrms, 400 Hz, worst case voltage excursion and user voltage tolerance envelope as specified in Table I. Voltage transients of 5 percent or less may occur several times an hour. The time to reach the transient maximum may vary from 0.001 to 0.1 seconds. The sudden application of user equipment to the Type III, 400 Hz electric power system may cause the voltage to decrease to the transient voltage minimum within 0.001 to 0.1 seconds. The voltage may then increase to a maximum value that is above the nominal voltage by an amount equal to ⅓ to ⅔ of the minimum transient voltage drop at a rate equal to 50 to 100 percent of the nominal voltage per second. Recovery to within the user voltage tolerance envelope will occur within 0.25 seconds. The sudden removal of user equipment from the Type III, 400 Hz electric power system may cause the voltage to increase to the transient voltage maximum within 0.001 to 0.1 seconds. The voltage may then decrease to a minimum value that is below the nominal voltage by an amount equal to ⅓ to ⅔ of the maximum transient voltage rise at a rate equal to 50 to 100 percent of nominal voltage per second. Recovery to within the user voltage tolerance envelope will occur within 0.25 seconds.

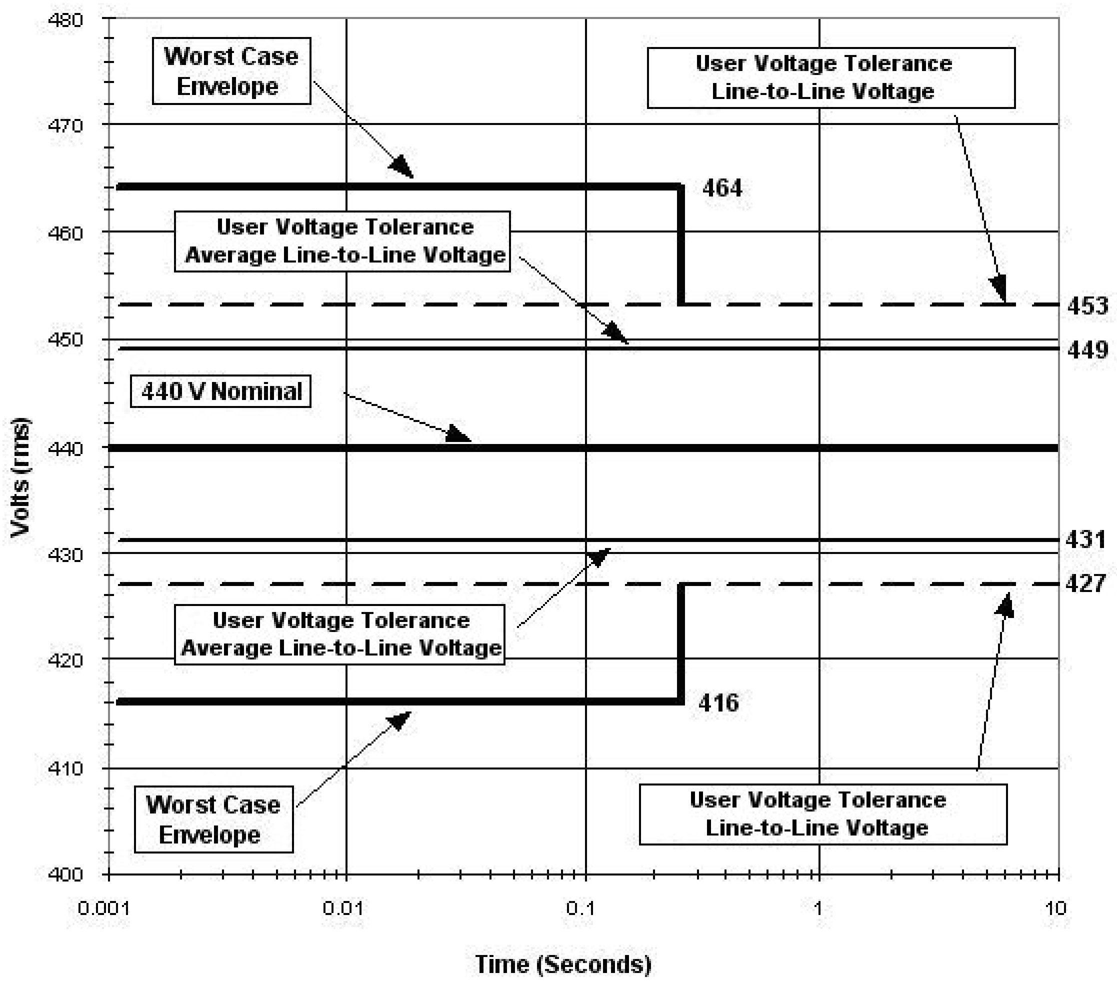


FIGURE 14. Type III, 440 Vrms, 400 Hz power - worst case and user voltage tolerance envelopes.

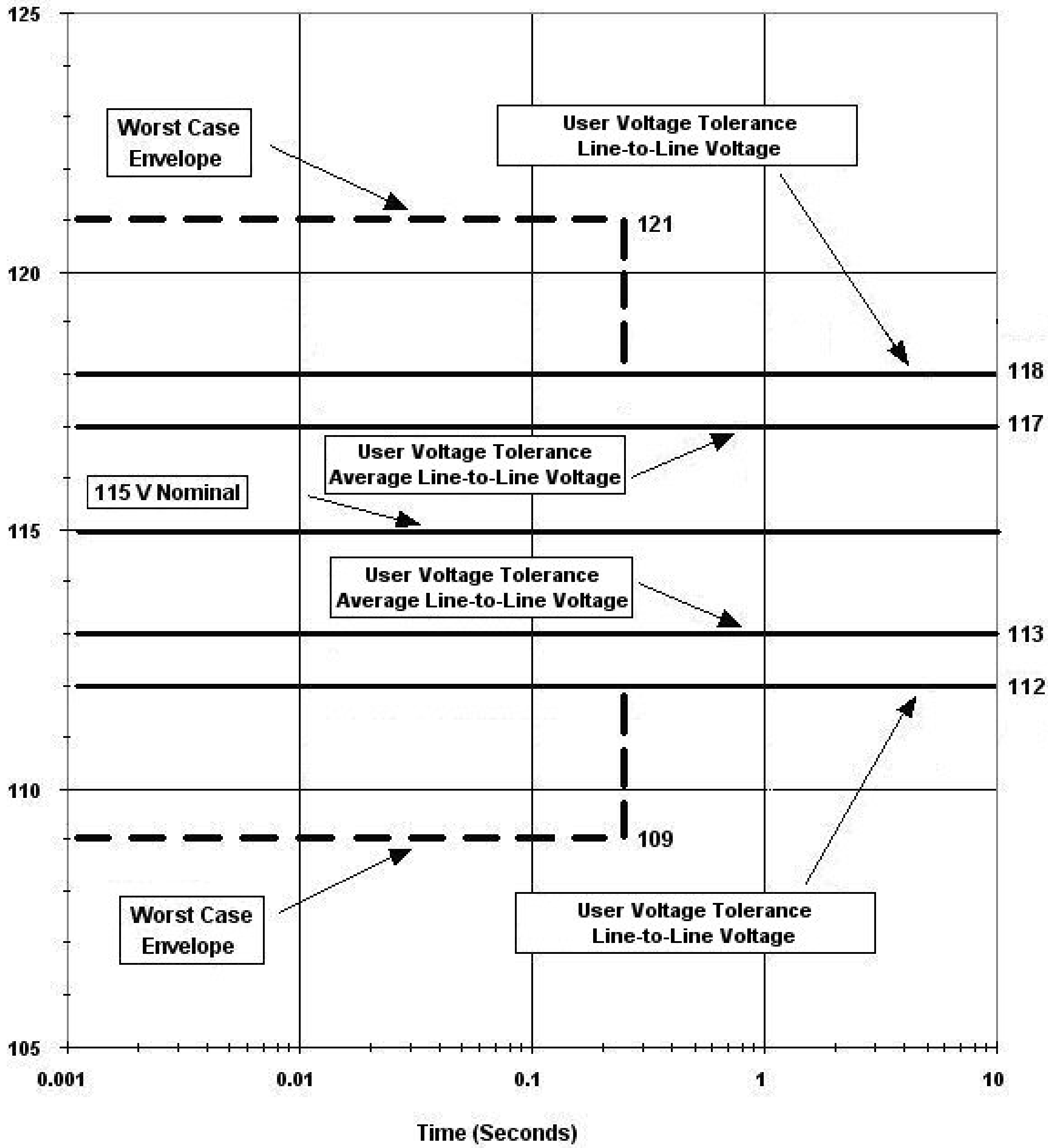


FIGURE 15. Type III, 115 Vrms, 400 Hz power - worst case and user voltage tolerance envelopes.

5.1.6.2.3 Voltage spike characteristics. Voltage spikes of 2,500 V peak on 440 Vrms systems, 1400 V peak on 230 Vrms systems (special power classification), and 1,000 V peak on 115 Vrms systems may be present on the electrical power system between line-to-line and between line-to-ground (or neutral). Approximately 50 spikes per week occur on the power system. The amplitude and waveform of voltage spikes will vary depending on system parameters. It should be noted that over an equipment design life of 20 years, approximately 50,000 spikes of varying amplitude will be encountered. Equipment shall remain operational before, during, and after experiencing a voltage spike with the characteristics shown in Figure 6. Equipment shall not experience any operational interruption, suffer any loss of data, or require a system restart or reboot.

5.1.6.3 System power factor (pf). Shipboard electric power systems are designed to operate with a pf of 0.8 lagging to 0.95 leading for 60 Hz power systems and 0.8 lagging to 0.9 leading for 400 Hz power systems.

5.2 User equipment interface requirements. User equipment shall meet the requirements specified in 5.2.1 through 5.2.13 to ensure compatibility with the electrical power system characteristics specified in Table II.

5.2.1 Compatibility. The construction of user equipment utilizing electric power shall be compatible with the electric power system characteristics as specified in 5.1.

5.2.2 User equipment voltage. Voltage preference shall be as follows (see 5.1.6.2):

a. User equipment rated above 5 kilovolt amperes (kVA) shall operate from 440 Vrms, 3-phase input power.

b. User equipment rated 5 kVA or less shall operate from 440 Vrms, 3-phase input power. Where such an input is not practical, the following shall be the order of preference:

(1) 115 Vrms, 3-phase

(2) 115 Vrms, single-phase

(3) 440 Vrms, single-phase

c. Special equipment, 115/200 Vrms, 3-phase, 4-wire, grounded neutral, 400 Hz power shall be provided for servicing aircraft in hangars and on flight decks, and to avionic shops.

d. Special equipment, 230 Vrms, 60 Hz, 3-phase, ungrounded or 230 Vrms, 60 Hz, single-phase, grounded or ungrounded. This power is provided upon request only for NATO load equipment.

e. Special equipment, 120/208 Vrms, 60 Hz, single-phase, grounded neutral or 240/120 Vrms, 60 Hz, single-phase, grounded neutral. 120 Vrms, single-phase grounded neutral loads shall be limited to 5 kVA. Equipment utilizing these special distribution system voltages shall be in accordance with NAVSEA Standard Drawing 7512881 and NAVSEA Standard Drawing 7598285, respectively.

5.2.3 Emergency conditions. User equipment shall withstand without damage electric power interruptions, rapid reapplications of power (see 5.1.3) and the emergency conditions specified in Table I and testing described in 5.3.4. The PDA shall make the determination as to whether the equipment is identified as Mission Critical Equipment (MCE) and must operate through the emergency conditions.

5.2.4 Grounding. User equipment, except for equipment on special voltage (grounded system (see 5.2.2 (c) and (d)), shall be ungrounded as related to the electric power system ground. Where power line filters are required in the user equipment, a line-to-line configuration is preferred. If a line-to-ground configuration is used for filtering, then the value of the filter capacitance shall not exceed 0.1 microfarad per line-to-ground for 60 Hz equipment and 0.02 microfarad per line-to-ground for 400 Hz equipment for all nominal user voltages. Filters shall use balanced capacitance per line-to-ground with a tolerance value not exceeding 10 percent. Line-to-ground current due to filters, etc., shall not exceed 30 milliamperes per line-to-ground. If performance or operational needs of user equipment require an electrical ground either solidly or by means of capacitors which exceed the values stated above or if the line-to-ground current exceeds 30 milliamperes per line-to-ground, then that equipment shall be electrically isolated from the power system. The neutral connection to user equipment on special voltage systems shall not be grounded at the user equipment.

5.2.4.1 Human body leakage current limits for personnel safety. In order to evaluate user equipment for potential shock hazards, a test using an impedance network simulating human body impedance shall be conducted on all equipment that requires a dedicated ground conductor or connection path to the ship's hull. The test simulates the worst case current path through the human body to a neutral point ground if the equipment ground connection is opened. The neutral point ground can be formed aboard ship by other equipment's line-to-ground filters. Simulated human body leakage current shall be measured from single-phase user equipment connected across one single-phase (line-to-line of a delta source or line-to-neutral of a wye source) of a three-phase transformer aboard ship, from single-phase equipment connected across two phases (line-to-line of a wye source) of a three-phase transformer aboard ship and from three-phase user equipment, using the tests in 5.3.9. Human body leakage current test limits are defined for two frequency ranges.

NOTE: Equipment utilizing non-standard power should not be used at voltages sourced by a line-to-line wye that are greater than 220 Vrms nominal or at frequencies that are greater than 60 Hz nominal as the human body leakage current measured in the Simulated Human Body Leakage Current Test in 5.3.9 will exceed the limit even though the equipment may be utilizing a filter containing the maximum allowable capacitance to ground of 0.1 uF. The two phase voltages producing the line-to-line voltage are separated by 120 degrees, not 180 degrees and do not sum to zero; the resultant voltage will produce a corresponding current.

5.2.4.1.1 Low frequency human body leakage current limits for personnel safety. Low frequencies include the input power fundamental and harmonics up to 700 Hz. The current limit through the impedance network simulating the human body for the test in 5.3.9 for the low frequency range is 5 milliamperes.

5.2.4.1.2 High frequency human body leakage current limits for personnel safety. High frequencies include those greater than 700 Hz and less than 100 kHz. The requirement to conduct a high frequency test shall be determined from an evaluation of the conversion technology (switching frequency) included in the equipment design. Any power-switching converter operating at a frequency above 1 kHz shall be tested. The current limit through the impedance network simulating the human body for the test in 5.3.9 for the high frequency range is 70 milliamperes.

5.2.5 Current (load) unbalance. User equipment comprised of a combination of single-phase and three-phase loads shall have a resulting input three-phase line current unbalance not exceeding 5 percent (submarines 3 percent) of the user equipment rating under normal operating conditions and during normal operating modes. This shall be measured with a voltage source having a line voltage unbalance less than 1 percent. Three-phase current unbalance shall be calculated as defined in 3.5.1. This requirement does not apply to aircraft servicing systems that are designed for a maximum current unbalance of 15 percent of the user equipment rating.

5.2.6 User equipment power factor. User equipment shall operate within the user frequency and voltage tolerance envelope of Figures 9 through 15 as applicable with a pf within the range of 0.8 lagging to 0.95 leading for 60 Hz and 0.8 lagging to 0.9 leading for 400 Hz under normal steady state operating conditions, excluding start-ups and pulsing loads.

5.2.7 Pulsed load. Pulsed load limits of percent generator kVA rating versus load lagging power factor for Types I, II, and III power shall be determined from Figure 16.

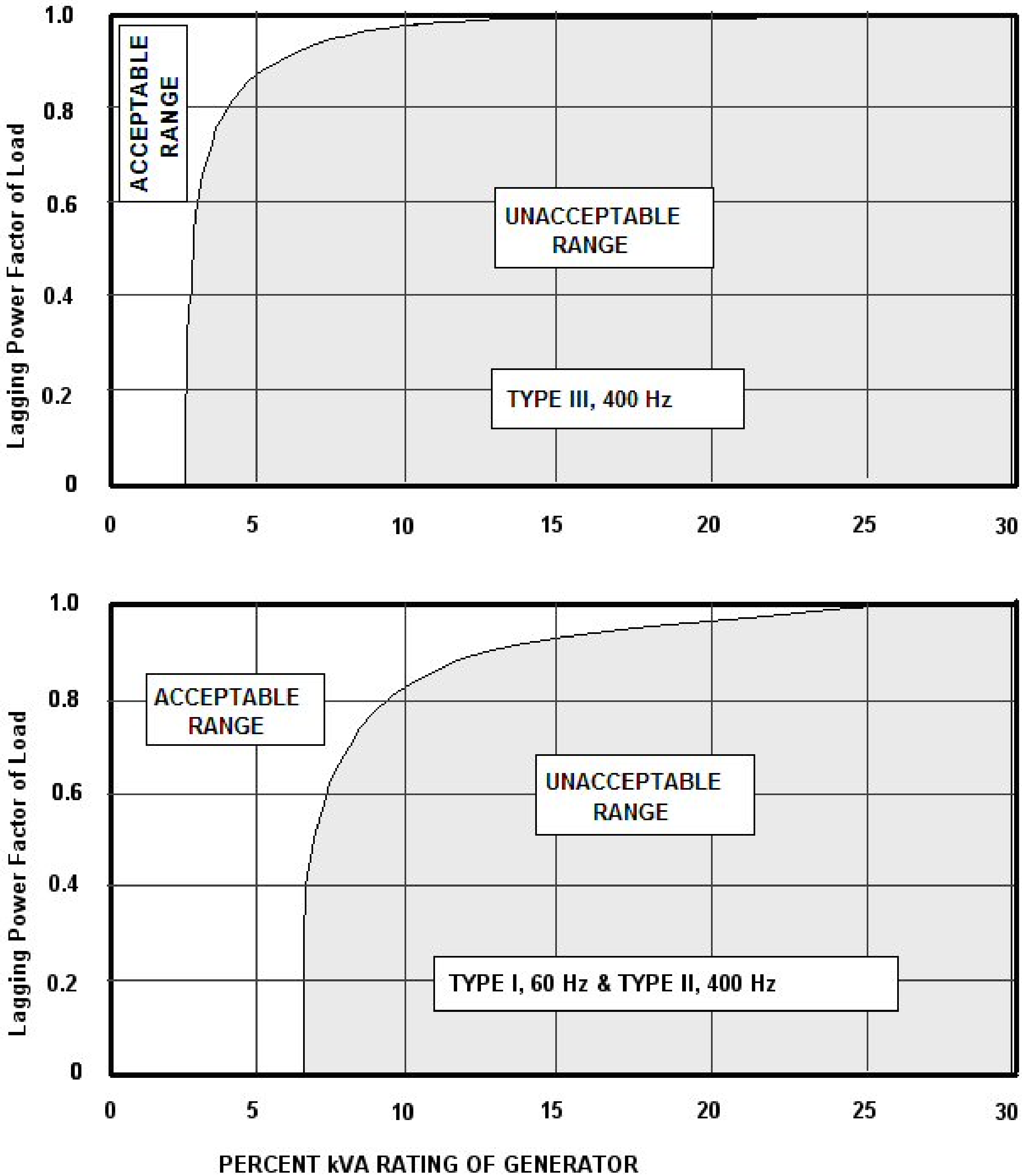


FIGURE 16. Pulsed load limits for rotating machine power sources.

5.2.8 Ramp load. Ramp loading shall be limited to an average of 30 percent of source rating in kVA per second. No step shall be greater than that specified for pulsed loads (see 5.2.7).

5.2.9 Input current waveform. The operation of user equipment shall cause minimum distortion on the electrical distribution system current waveform. Harmonic current and other conducted emissions (within the 20 kHz frequency band) introduced by the load are limited in order to allow the source and distribution system to maintain the bus voltage distortion within specified limits. Single frequency limits for 60 Hz and 400 Hz user equipment at the nominal user voltage levels of Table I are depicted in Figures 17, 18, 19, and 20. The criteria defined in Figures 17 and 18 are similar to the MIL-STD-461 limit criteria for the EMI test CE101 for 60 Hz fundamental tailored to 20 kHz. Harmonic current shall be measured at nominal voltage input for all operating modes.

5.2.9.1 60 Hz user equipment greater than or equal to 1 kVA. The operation of user equipment or the aggregate with power ratings ≥ 1 kVA shall not cause single harmonic line current or current of any frequency above the fundamental at 60 Hz to 2000 Hz to be generated that is greater than the limit line set at 3 percent of the unit's full rated load fundamental current. Additionally, harmonic line current or current of any frequency above 2000 Hz through 20 kHz shall not exceed the limit line set at 6000/f percent of the user equipment's full load fundamental current, where f is the nominal frequency. This is shown in Figure 17. User equipment, for the purposes of this requirement, shall be defined as a system with a standalone unit or the aggregate of a system with multiple like units on a single bus, e.g. lighting source power supplies. The rating of equipment with multiple power inputs from the same interface shall be the summation of all the power inputs under steady-state conditions.

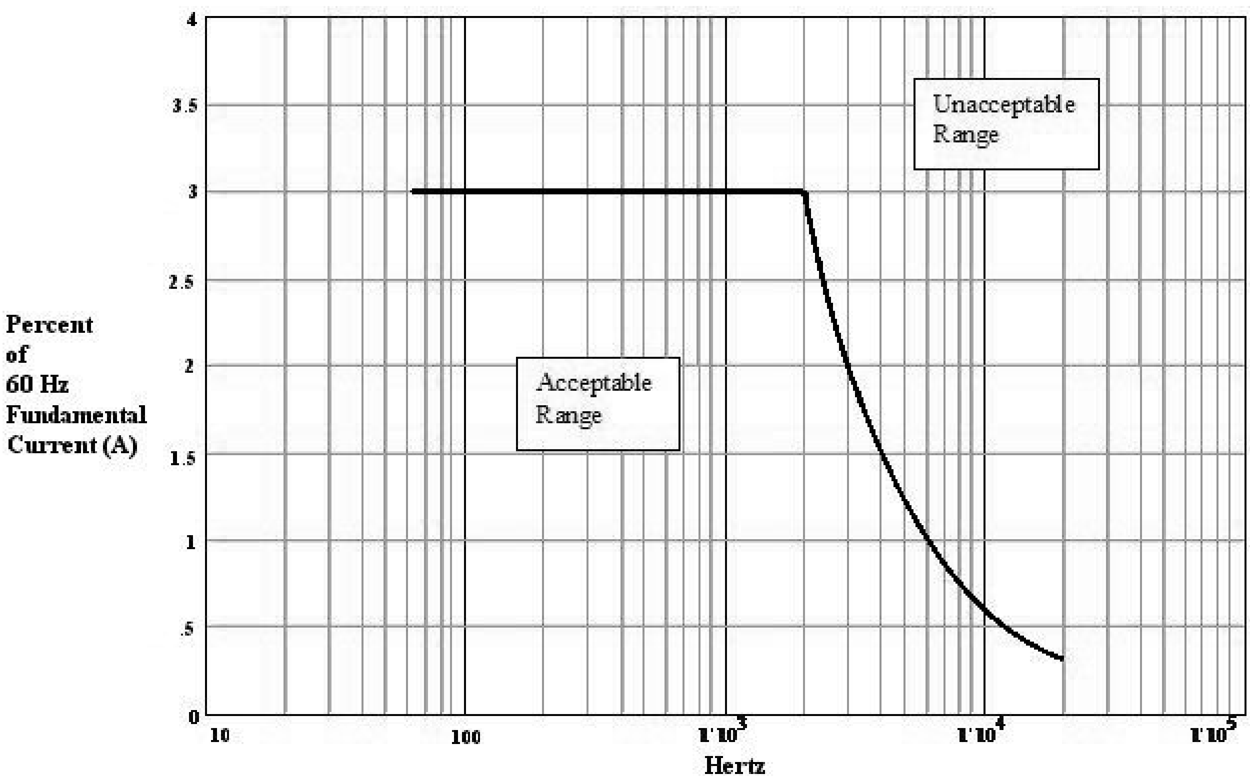


FIGURE 17. Limit line for currents at frequencies greater than 60 Hz for equipment greater than or equal to 1 kVA.

5.2.9.2 60 Hz user equipment less than 1 kVA. The operation of user equipment with power ratings < 1 kVA shall be current amplitude limited so that no individual harmonic line current or current of any frequency above the fundamental at 60 Hz to 20 kHz shall exceed the limit line set at a magnitude of 6000/f percent of the user equipment's full load fundamental current where f is the frequency. This is shown in Figure 18.

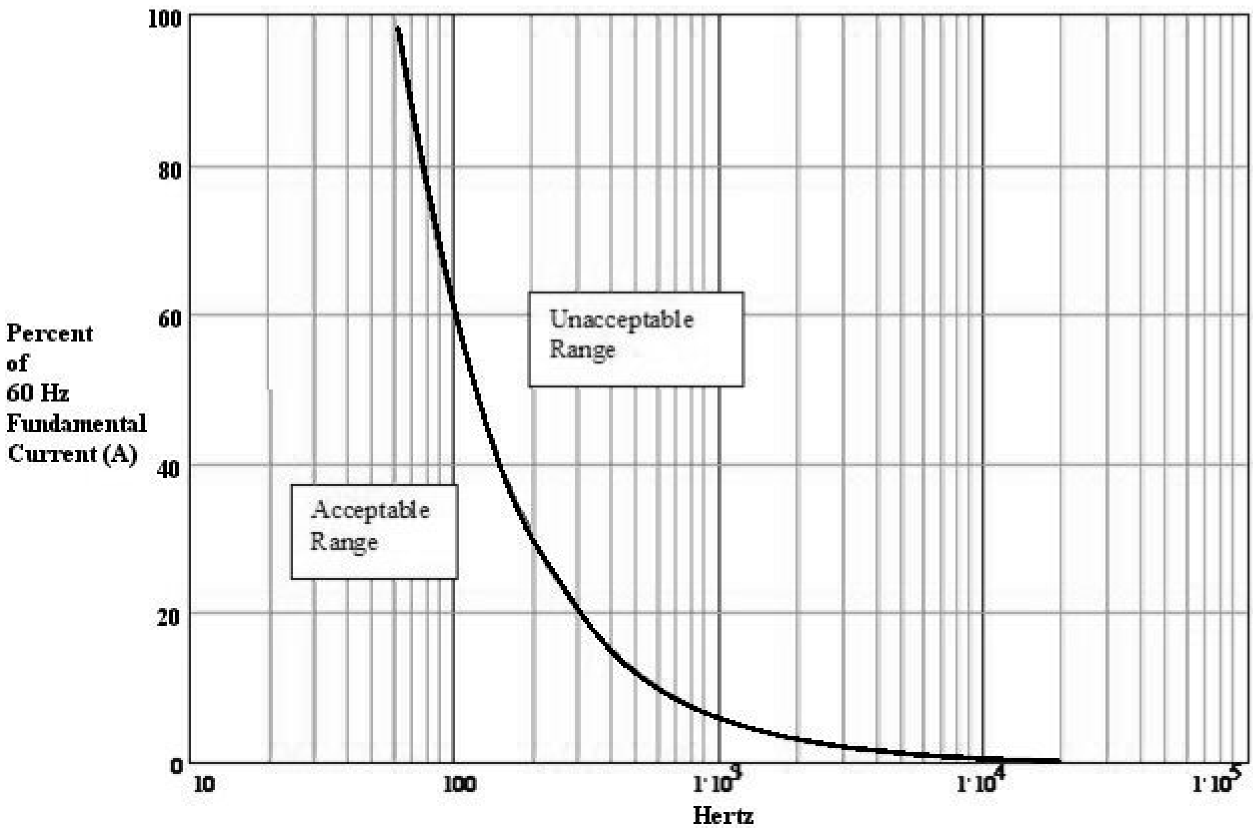


FIGURE 18. Limit line for currents at frequencies greater than 60 Hz for equipment less than 1 kVA.

5.2.9.3 400 Hz user equipment greater than or equal to 0.2 kVA. The operation of user equipment or the aggregate with power ratings ≥ 0.2 kVA shall not cause single harmonic line current or current of any frequency above the fundamental at 400 Hz to 13.33 kHz to be generated that are greater than the limit line set at 3 percent of the unit's full rated load fundamental current. Additionally, harmonic line current or current of any frequency above 13,334 Hz through 20 kHz shall not exceed the limit line set at 40,000/f percent of the user equipment's full load fundamental current, where f is the frequency. This is shown in Figure 19. User equipment, for the purposes of this requirement, shall be defined as a system with a standalone unit or the aggregate of a system with multiple like units on a single bus, e.g. lighting source power supplies. The rating of equipment with multiple power inputs from the same interface shall be the summation of all the power inputs under steady-state conditions.

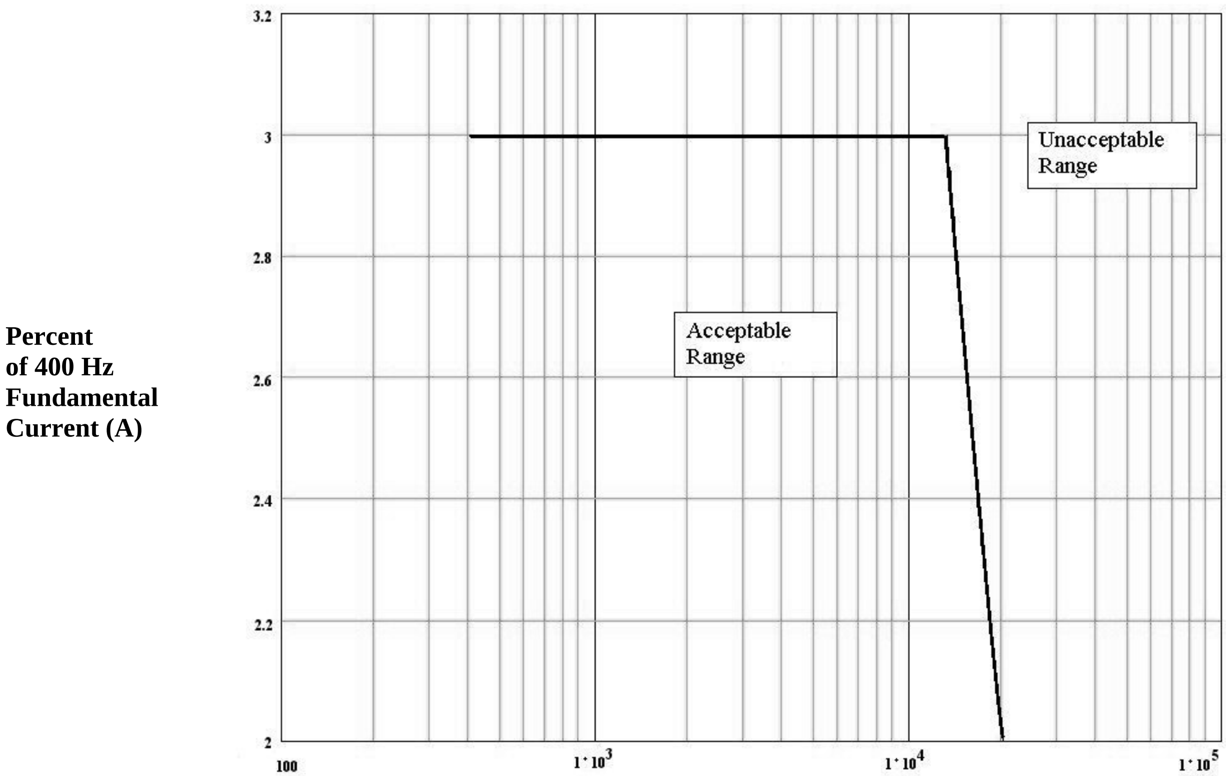


FIGURE 19. Limit line for currents at frequencies greater than 400 Hz for equipment greater than or equal to 0.2 kVA.

5.2.9.4 400 Hz user equipment less than 0.2 kVA. The operation of user equipment with power ratings < 0.2 kVA shall be current amplitude limited so that no individual harmonic line current or current of any frequency above the fundamental at 400 Hz to 20 kHz shall exceed the limit line set at a magnitude of 40,000/f percent of the user equipment's full load fundamental current, where f is the frequency. This is shown in Figure 20.

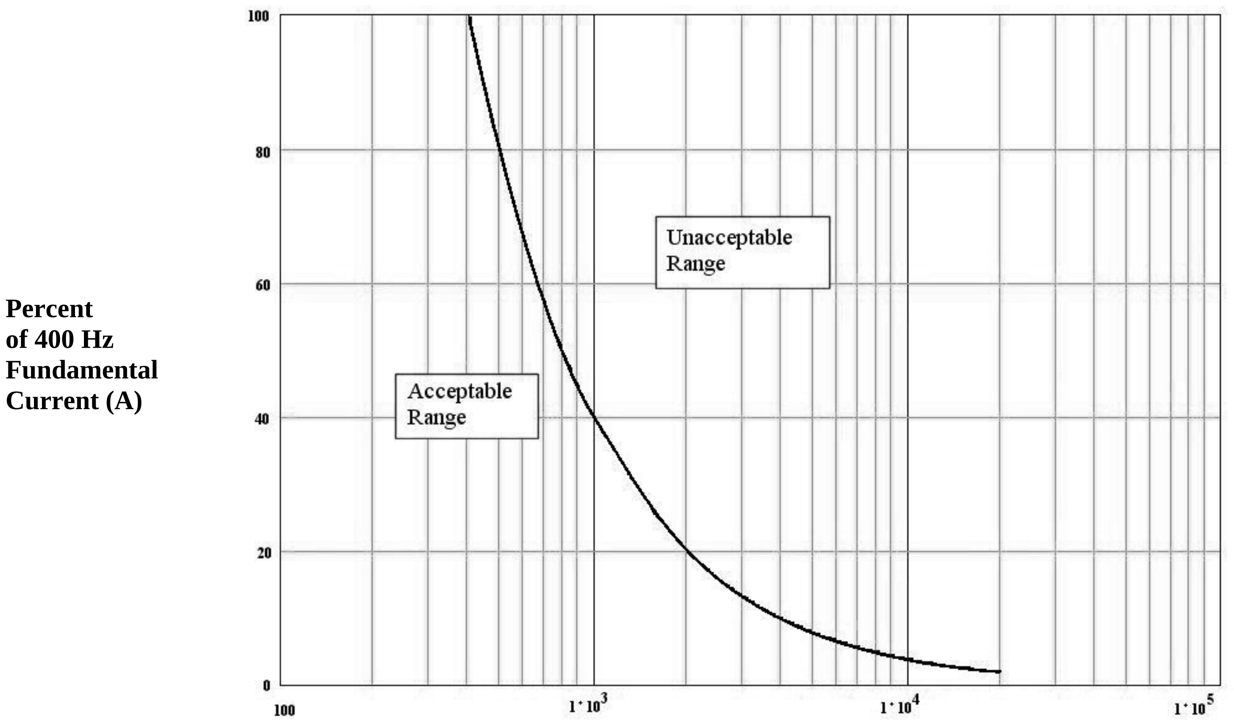


FIGURE 20. Limit line for currents at frequencies greater than 400 Hz for equipment less than 0.2 kVA.

5.2.9.5 User equipment in the unacceptable range. When user equipment cannot meet the input current waveform limits specified in 5.2.9.1, 5.2.9.2, 5.2.9.3, or 5.2.9.4 a technical review of the outage shall be performed to determine its impact. Options that may be taken include a waiver, deviation, or electrical isolation.

5.2.10 Surge/inrush current. User equipment shall be constructed to limit the ratio of surge current to normal operating current. The ratio of the maximum surge/inrush peak current to the full nominal load rms current shall be limited to the value determined from Figure 21 for Type I, 60 Hz electric power and Figure 22 for Types II and III, 400 Hz electric power. Load sequencing may be required to maintain an acceptable user voltage envelope at the user interface. Surge/inrush current shall be measured, recorded, and evaluated when energizing the user equipment at the nominal input voltage when the voltage source sine-wave passes through 0 degrees for inductive load equipment or when the sine-wave passes through 90 degrees for capacitive load equipment. Multiple surge/inrush current occurrences observed on the same event shall be addressed and evaluated individually to determine compliance with the above requirements.

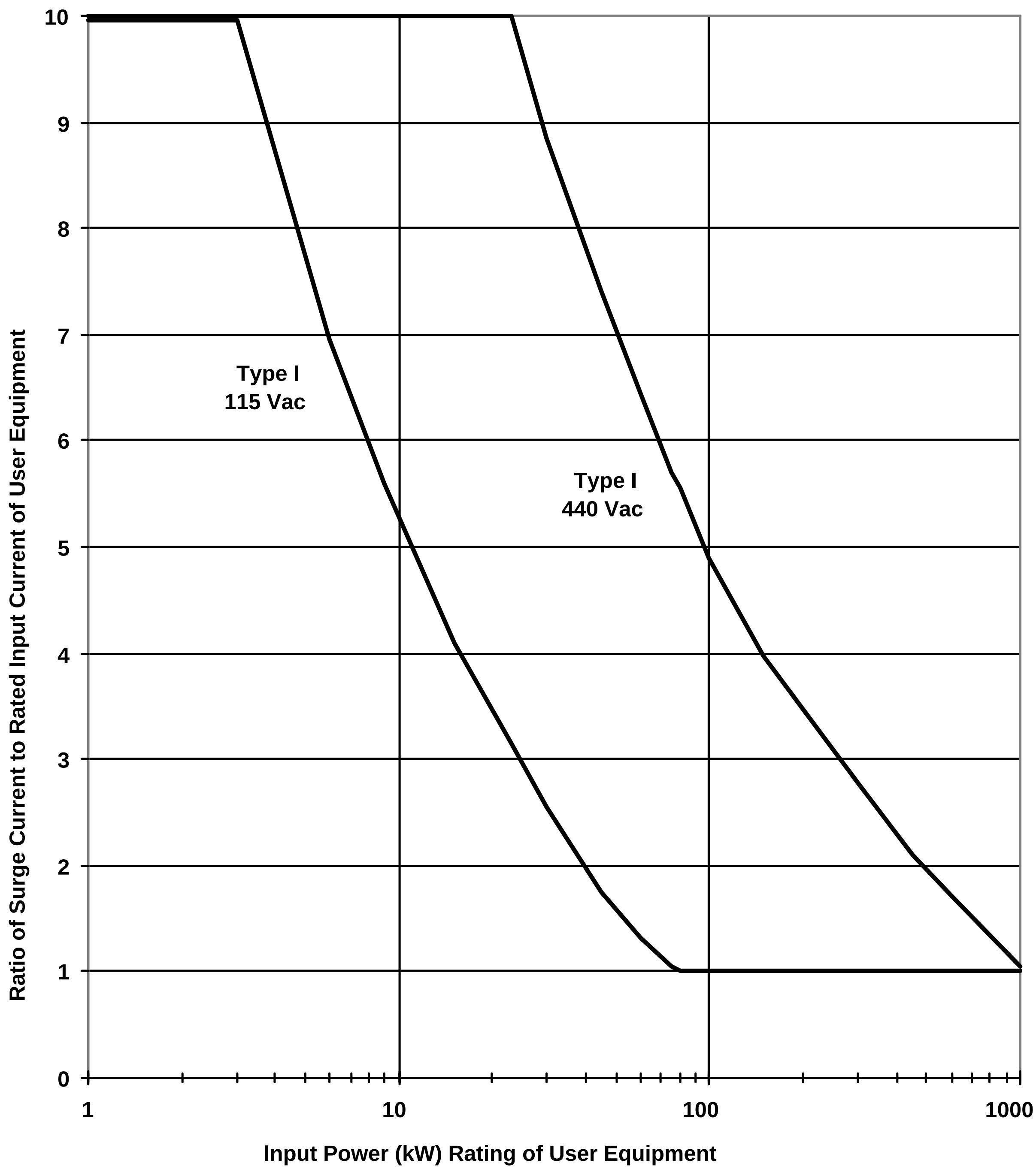


Figure 21. Surge current limits for load equipment using Type I power.

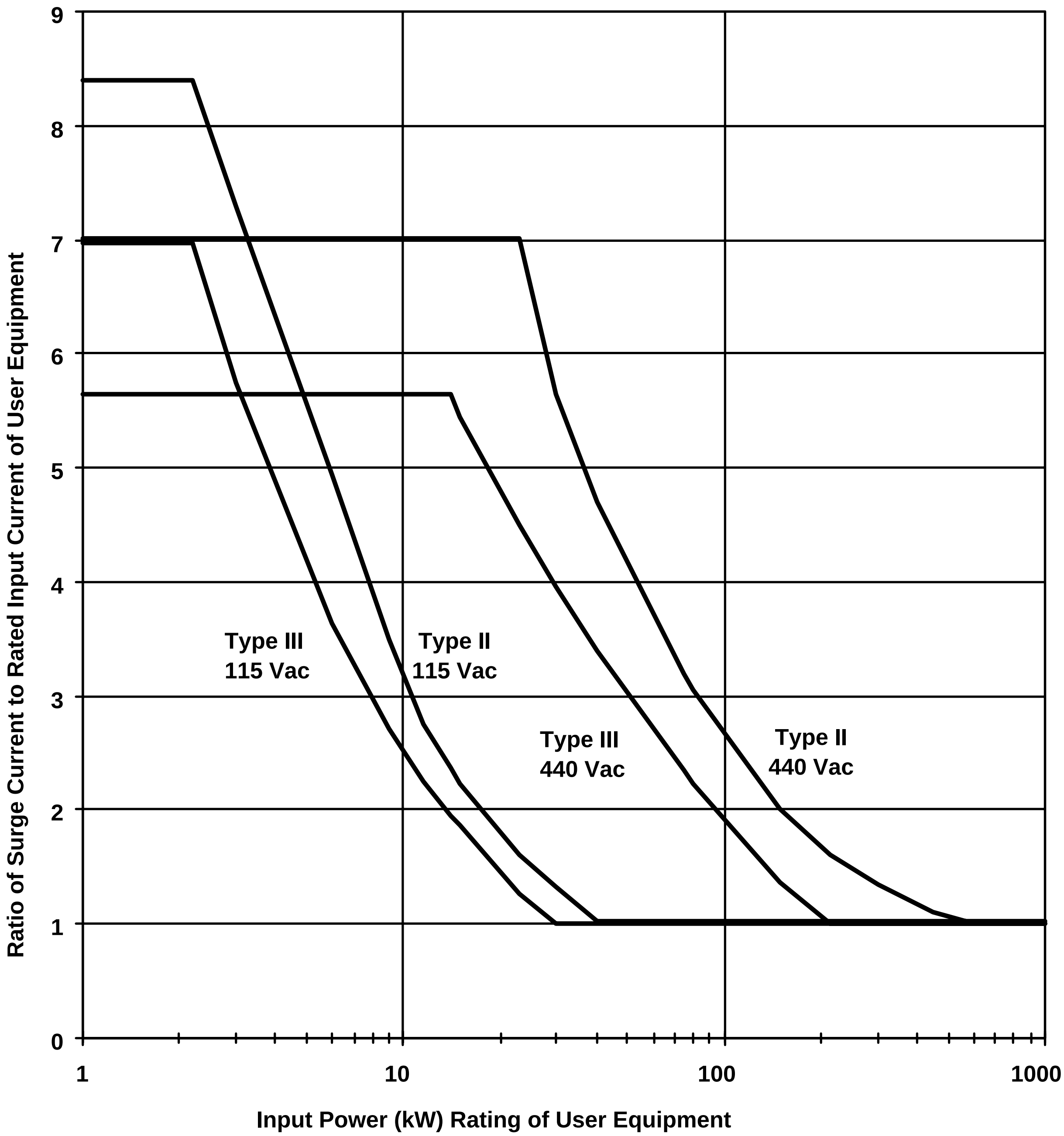


FIGURE 22. Surge current limits for load equipment using Type II or III power.

5.2.11 Insulation resistance. When un-energized, user equipment shall tolerate the application of 500 VDC by a megohmmeter insulation resistance tester between each power conductor and ground without equipment damage, arc-over, degradation, or abnormal operation. NSTM Chapter 300 procedures may be used as a guide. The resistance to ground value as measured by the megohmmeter shall be equal to or greater than 10 Mohms as identified in MIL-E-917.

5.2.12 Active ground detection. When energized, user equipment rated at nominal 440 Vrms shall tolerate the additional application of 150 VDC between each power conductor and ground without equipment damage, arc-over, degradation, or abnormal operation. When energized, user equipment rated less than nominal 440 Vrms shall tolerate the additional application of 50 VDC between each power conductor and ground without equipment damage, arc-over, degradation, or abnormal operation.

5.2.13 Passive ground detection. Passive ground detection is accomplished by using the visual intensity of indicator lights connected from line to ground to determine grounded conditions. User equipment shall operate at nominal voltages.

5.3 Test requirements. This section specifies test requirements and the associated test procedures. User equipment test requirements are intended to verify compliance to the user equipment interface requirements in this standard when tested in accordance with the procedures specified herein (see 6.2). For user equipment testing, the hardware and software of a Unit Under Test (UUT) shall be representative of production. NAVSEA reserves the right to tailor test requirements.

5.3.1 Voltage and frequency tolerance test. This test shall be used to evaluate the performance of user equipment under the voltage and frequency conditions of Table II, as applicable. The operation of the user equipment shall be within the manufacturer's defined operating parameters when tested to the voltage and frequency conditions of Table II, as applicable.

TABLE II. Voltage and frequency tolerance test.

	User voltage tolerance (Vrms)			**Frequency tolerance (Hz)**		
	Lower limit	**Nominal**	**Upper limit**	**Lower limit**	**Nominal**	**Upper limit**
Type I, 3-phase	107 409	115 440	123 471	58 (57 for submarines)	60	62 (63 for submarines)
Type I, 3-phase, grounded	186	200	214	58	60	62
Type I, 1-phase	107 409	115 440	123 471	58 (57 for submarines)	60	62 (63 for submarines)
Type I, 1-phase, grounded	107	115	123	58	60	62
Type II, 3-phase	107 409	115 440	123 471	380	400	420
Type II, 1-phase	107 409	115 440	123 471	380	400	420
Type III, 3-phase	112 427	115 440	118 453	398	400	402
Type III, 3-phase, grounded	194	200	206	398	400	402
Type III, 1-phase	112 427	115 440	118 453	398	400	402
Type III, 1-phase, grounded	112	115	118	398	400	402

5.3.1.1 Apparatus. The following apparatus is recommended for performing this test:

a. Power source of required capacity and range of voltage and frequency adjustments. A power source with a capability of having an independently programmable voltage and frequency output is recommended.

b. Voltmeters (true rms) - ±0.5 percent accuracy.

c. Frequency meter - ±0.5 Hz accuracy.

d. Temperature meter - ±0.5 °C accuracy.

5.3.1.2 Procedure. The user equipment shall first be operated in a normal operating mode within the steady-state voltage and frequency tolerance envelopes as identified in Figures 9 through 15 until the equipment temperature has stabi1ized. Temperature stability shall be defined as when the variation between successive temperature measurements at the same location does not exceed 1 °C after 30 minutes. The user equipment shall then be subjected to the limits of the user voltage and frequency tolerance envelopes of Table II. Set the following combinations:

a. voltage upper limit and frequency upper limit

b. voltage upper limit and frequency lower limit

c. voltage lower limit and frequency lower limit

d. voltage lower limit and frequency upper limit

The user equipment shall be operated at each combination until its temperature has stabilized and for 30 minutes thereafter. This test shall be repeated for each mode of equipment operation. Voltage, frequency, and internal equipment temperatures shall be measured and recorded at 10-minute intervals. During and after testing, equipment shall operate normally with a stable temperature and with no operational degradation to show compliance with this test.

5.3.2 Voltage and frequency transient tolerance and recovery test. The user equipment performance shall be evaluated under the transient frequency and voltage conditions (from nominal) specified in Table III. Frequency testing can be accomplished on a component basis in lieu of larger modules or complete unit testing.

TABLE III. Transient voltage and frequency tolerance and recovery test.

Condition	**Type I power**		**Type II power**		**Type III power**	
	Voltage	**Frequency**	**Voltage**	**Frequency**	**Voltage**	**Frequency**
Upper limit	+20%	+5½ %	+20%	+6½%	+5½%	+1½%
Lower limit	-20%	-5½%	-20%	-6½%	-5½%	-1½%

5.3.2.1 Apparatus. The following apparatus is recommended for performing this test:

a. Power source of required capacity and range of voltage and frequency adjustments. A power source with a capability of having an independently programmable voltage and frequency output is recommended.

b. Voltmeters (true rms) - ±0.5 percent accuracy.

c. Frequency meter - ±0.5 Hz accuracy.

d. Storage oscilloscope having ≥ 500 kHz response per channel.

e. Current and potential transformers and probes as required.

f. Temperature meter - ±0.5 °C accuracy.

5.3.2.2 Procedure. The user equipment shall be operated in a normal operating mode within the user voltage and frequency tolerance envelopes as shown on Figures 9 through 15, as applicable, until the equipment temperatures have stabi1ized. Temperature stability shall be defined as when the variation between successive temperature measurements at the same location does not exceed 1 °C after 30 minutes. The input voltage and frequency shall then be simultaneously changed within 0.1 second to the applicable upper limit of Table III. Return the voltage and frequency to the user tolerance band within the applicable recovery time of Table I items 6 and 14. The initial condition of voltage, frequency, and line current shall be measured and recorded before the start of each test. Input voltages, frequency, and input line currents shall be recorded before initiation of the voltage and frequency transient and until the transient is completed. Repeat the test for the applicable lower limit of voltage and frequency given in Table III. Repeat the test for each normal mode of operation at the applicable upper and lower limits of transient voltage and frequency given in Table III. During and after testing, equipment shall operate normally with no operational degradation to show compliance with this test.

5.3.3 Voltage spike test. A voltage spike test shall be conducted to evaluate the capability of user equipment to withstand and operate before, during, and after the voltage spike as specified in Figure 6 (see 3.4.6). It is recommended the voltage spike be applied to the power leads at not more than 1.5 meters from the equipment input terminals. The test leads shall also be connected as close as possible to the input terminal of the user equipment.

5.3.3.1 Apparatus. The following apparatus is recommended for performing this test:

a. Power source of required capacity and range of voltage and frequency adjustments. A power source with a capability of having an independently programmable voltage and frequency output is recommended. The power source shall withstand the voltage spike test.

b. Voltage spike attenuation circuit – If necessary, to reduce the magnitude of the voltage spikes imposed on the power source during testing, between the power source and the test circuit, a metal oxide varistor (MOV) can be installed from each line-to-line connection from the power supply. The MOV shall be rated for the test to protect the power supply. Also, it may be necessary to connect a one-microfarad capacitor across each set of MOVs to filter out the high frequencies present on the leading edge of the voltage spike generated by the spike generator. After the parallel MOV and capacitor circuit placed across each line-to-line terminal, between the power source and the test circuit, a series inductor shall be installed in each line to prevent attenuation of the spike presented to the Unit Under Test (UUT). The inductance should be as high as practicable without causing a voltage drop of such magnitude that the input voltage to the UUT is below the limit specified in this standard. The current drawn by the UUT will determine the maximum allowable inductor value. Appropriate damping resistors should be connected across each inductor to eliminate unwanted oscillations.

c. Solar Spike Generator, Model 7399-1 or 2 (modified to accept an independent 60 Hz sync input that is required if the input power source that is used for the spike generator is not synchronized with the unit under test input power source) or equivalent.

d. Oscilloscope with a minimum bandwidth of 30 megahertz (MHz) and a high voltage probe.

e. Pearson wide-band current transformer or equivalent.

f. Rd (resistor, 1 ohm, 1 percent, 120 watt) voltage spike generator (VSG) output damping.

g. Cg (AC capacitors, 660 Vrms) to support the range 5 microfarad to 35 microfarad (typical: consisting of 5, 10, and 20-microfarad values).

h. Rs (two variable resistors: 0-1 ohm, 10 watt and 0-16 ohm, 50 watt, series connected).

i. Lg (inductor, 5.7 mH, 370 Vrms, 2 Amps) used in power Types II and III testing.

j. Plug-in box, line-to-ground, SOLAR Part Number 739950 or equivalent.

k. Transformer (440 Vrms to 115 Vrms, 50 VA) used for conditioning the Sync Input when conducting 440 Vrms voltage spike tests.

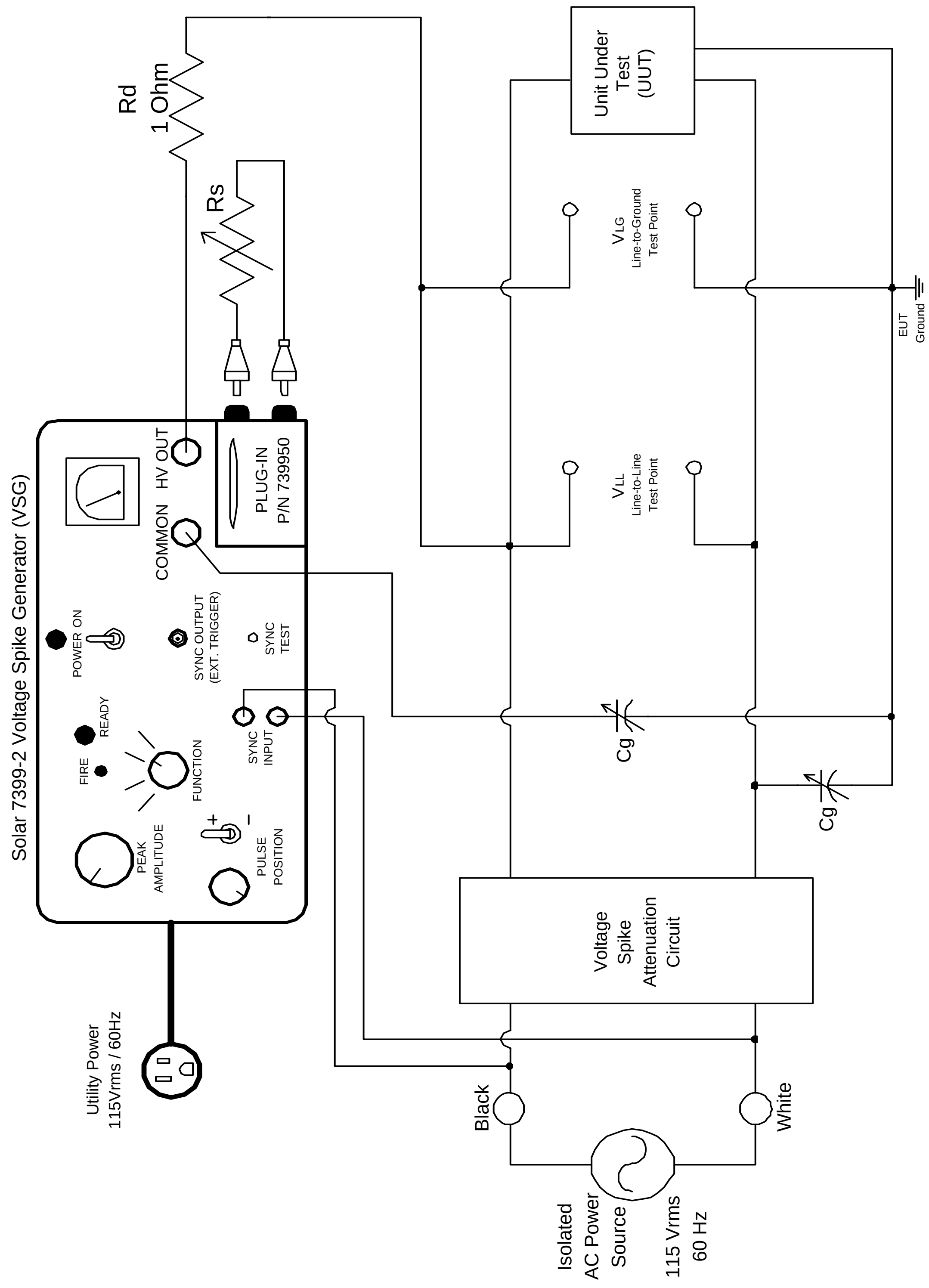
5.3.3.2 Procedure. Figures 23, 24, and 25 show the single-phase 115 Vrms, three-phase 115 Vrms, and three-phase 440 Vrms voltage spike test circuit configuration diagrams, respectively, for Type I power. Figures 26 and 27 show the voltage spike test circuit configuration diagrams for Types II and III power. For voltage spike calibration purposes, the user equipment shall be disconnected from the power source and the voltage spike waveform shown in Figure 6 shall be superimposed on the power source voltage. A one-ohm damping impedance shall be utilized in series with the high-voltage output line of the voltage spike generator. The voltage spike shall be calibrated between each power line to ground with the UUT disconnected, for the four synchronization positions shown in Tables IV and V. The voltage spike waveform shown in Figure 6 can be achieved between any two power lines or from the power line under test to ground. The voltage spike exhibited during open-circuit calibration shall have a peak value (including the fundamental AC waveform voltage) of 2,400 to 2,500 V peak for 440 Vrms system and 900 to 1,000 V peak for 115 Vrms systems. After establishing the open-circuit calibrated voltage spike, the user equipment shall be reconnected and five positive polarity voltage spikes at the rate of two per minute shall be applied at 0 degrees and five positive polarity voltage spikes at the rate of two per minute shall be applied at 90 degrees. Then, after reversing the “high voltage out” and “common” connections, five negative polarity voltage spikes at the rate of two per minute shall be applied at 0 degrees and five negative polarity voltage spikes at the rate of two per minute shall be applied at 270 degrees. The test shall be repeated for each line to ground; reconfigure the test circuit (the capacitor and, if required, parallel inductor to ground shall not be connected to the line having the spike applied, but to the remaining line or lines). The voltage spike test conditions are described in Table IV for single-phase systems and in Table V for three-phase systems. Respective line-to-ground voltage, line-to-line voltage, and spike current parameter data shall be monitored and recorded to ensure proper testing. Equipment shall remain operational before, during, and after each applied voltage spike. The UUT shall not experience any operational interruption, suffer any loss of data, or require a restart or reboot.

TABLE IV. Single-phase system voltage spike test conditions.

Spike peak (including fundamental AC voltage waveform)	Conductor-to-ground	Synchronization angle	Polarity	Source dampening impedance
2,400 to 2,500 V peak (440 Vrms systems) or 900 to 1,000 V peak (115 Vrms systems)	Black (hot)	0°	positive	1 ohm
		90°	positive	
		0°	negative	
		270°	negative	
	White (return)	0°	positive	
		90°	positive	
		0°	negative	
		270°	negative	

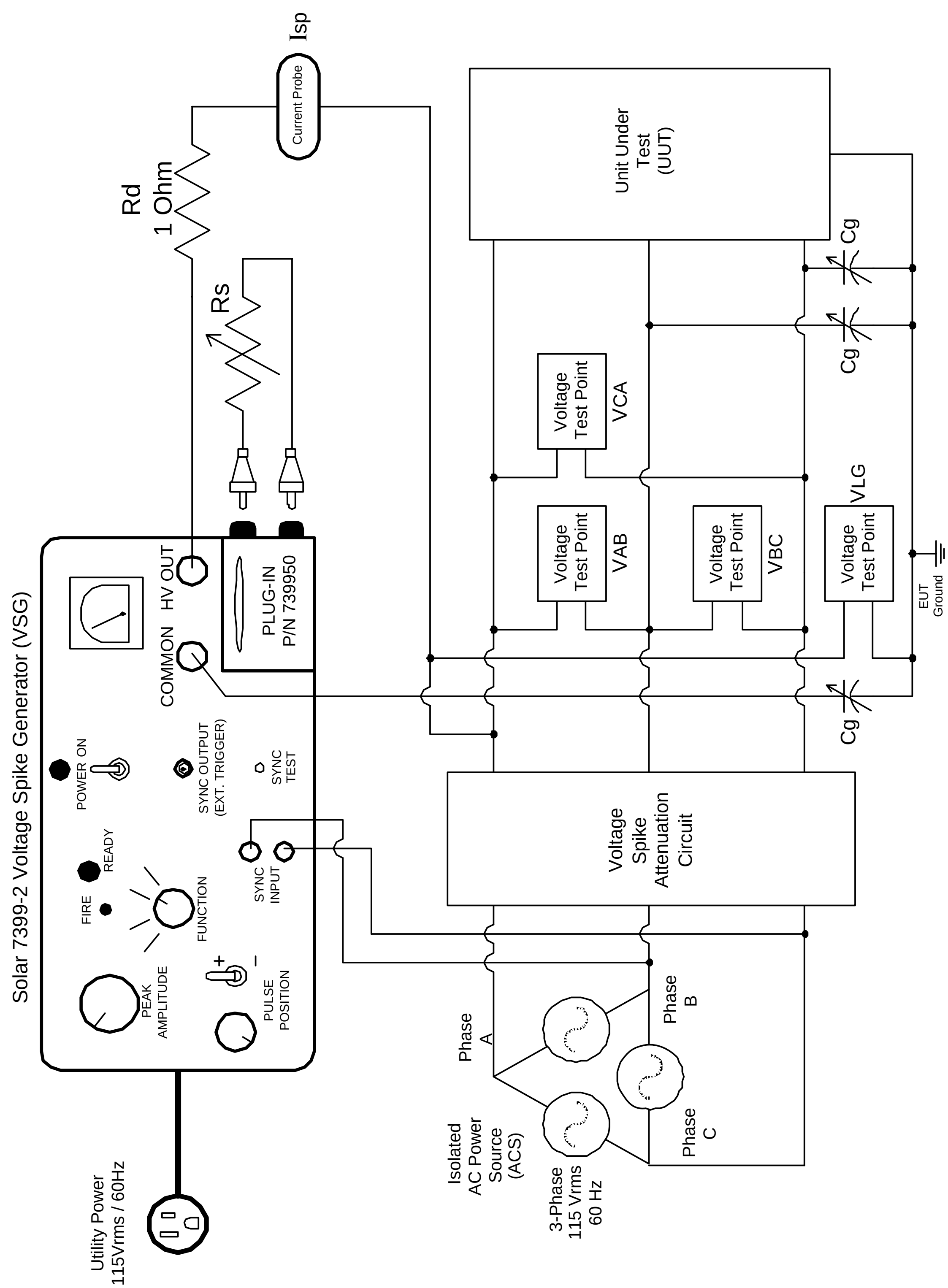
TABLE V. Three-phase system voltage spike test conditions.

Spike peak (including fundamental AC voltage waveform)	Conductor-to-ground	Synchronization angle	Polarity	Source dampening impedance
2,400 to 2,500 V peak (440 Vrms systems) or 900 to 1,000 V peak (115 Vrms systems)	Line A	0°	positive	1 ohm
		90°	positive	
		0°	negative	
		270°	negative	
	Line B	0°	positive	
		90°	positive	
		0°	negative	
		270°	negative	
	Line C	0°	positive	
		90°	positive	
		0°	negative	
		270°	negative	



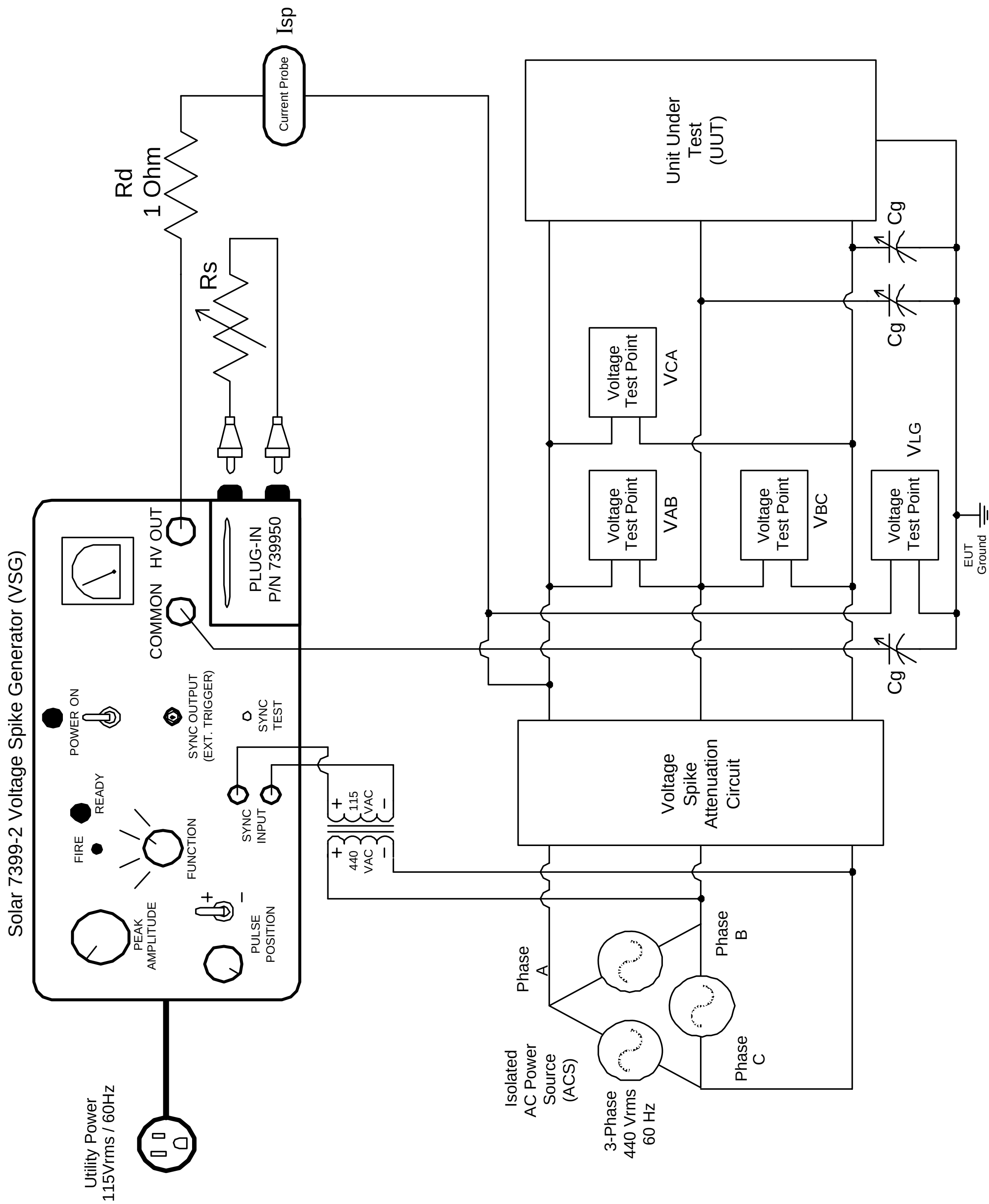
NOTE: 115 Vrms positive polarity black-to-ground test circuit is shown for illustrative purposes.

FIGURE 23. Single-phase, 115 Vrms, Type I power voltage spike test circuit configuration.



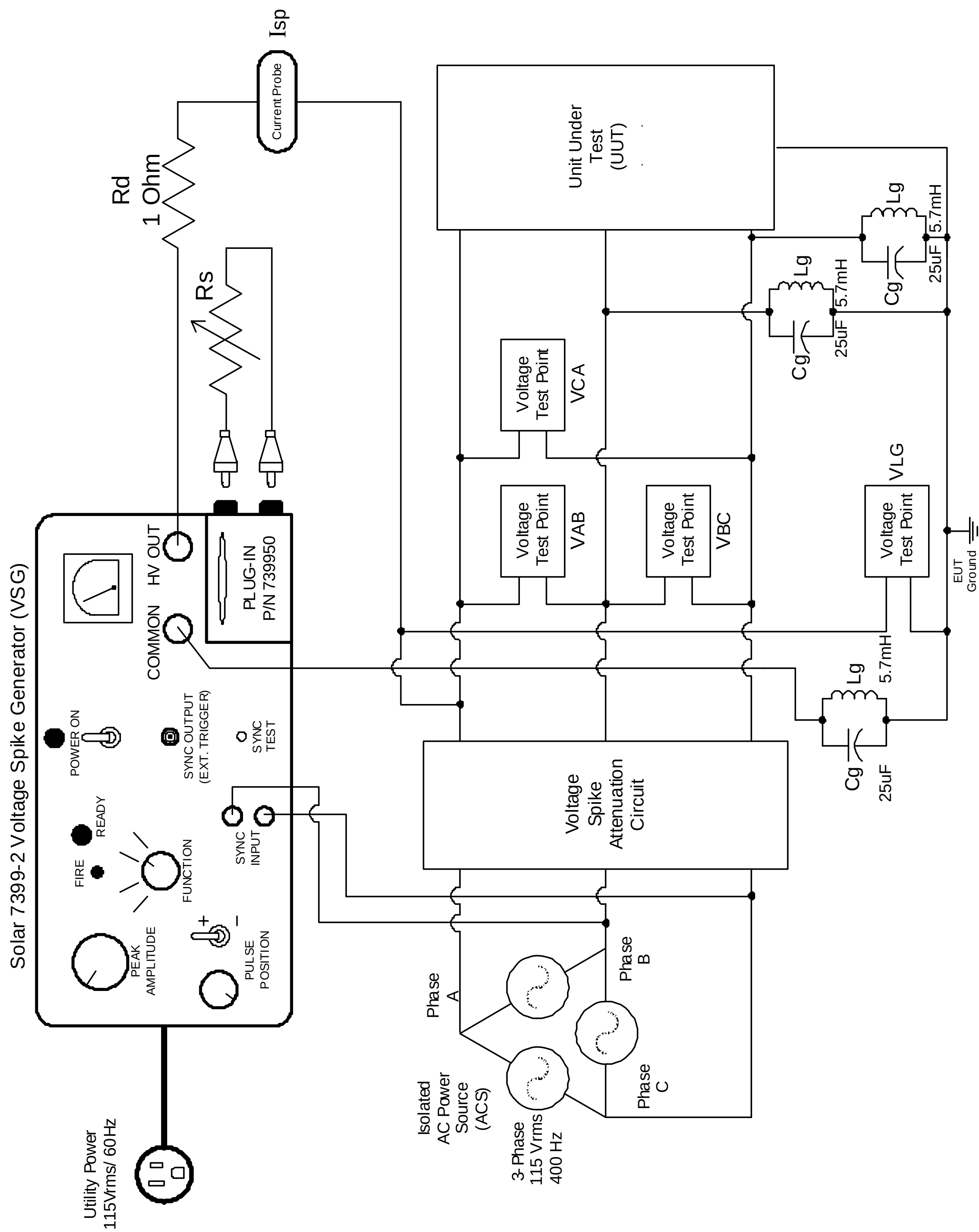
NOTE: Positive polarity Phase A-to-ground test circuit is shown for illustrative purposes.

FIGURE 24. Three-phase, 115 Vrms, Type I voltage spike test circuit.



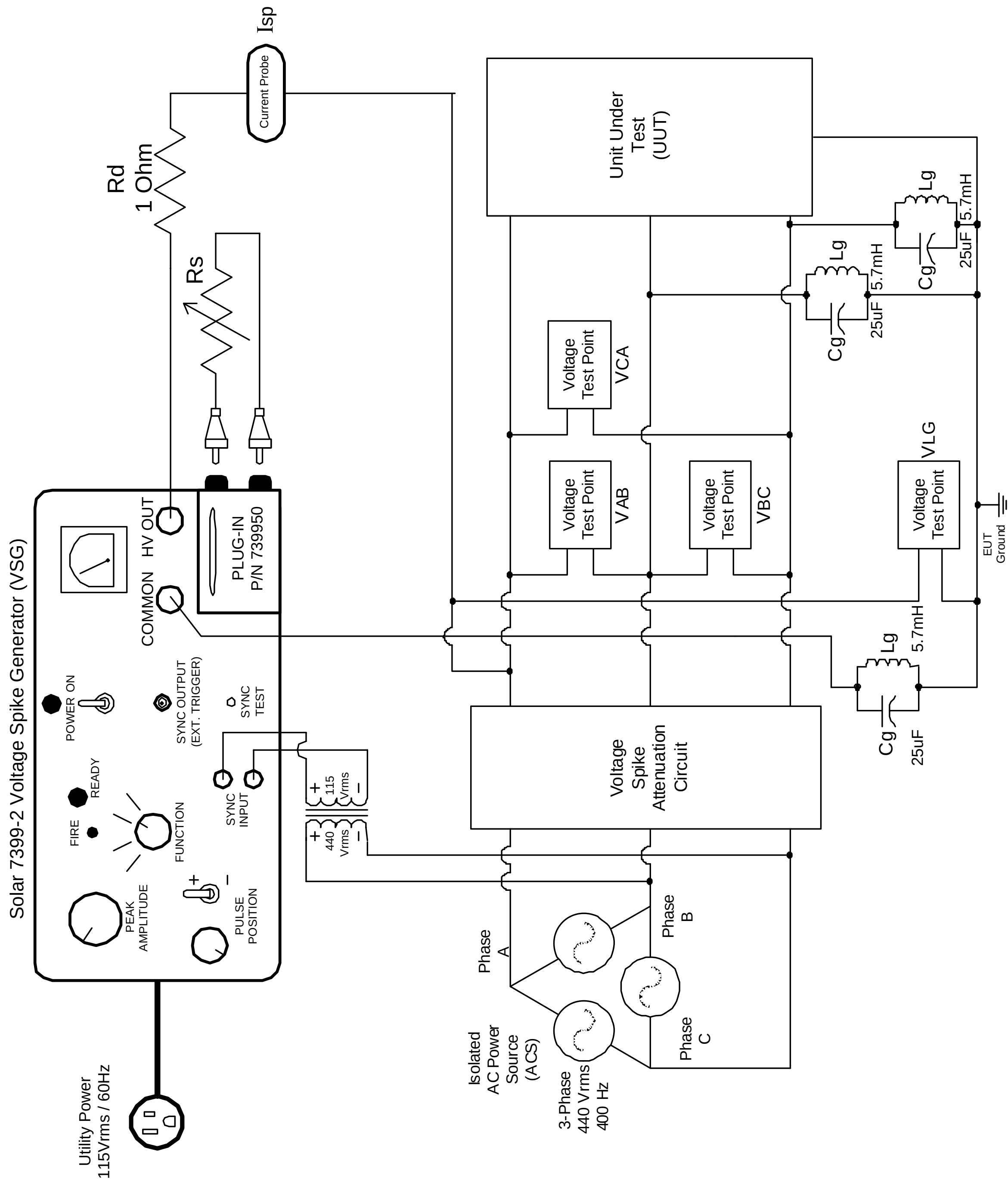
NOTE: Positive polarity Phase A-to-ground test circuit is shown for illustrative purposes.

FIGURE 25. <u>Three-phase, 440 Vrms, Type I voltage spike test circuit configuration</u>.



NOTE: Positive polarity Phase A-to-ground test circuit is shown for illustrative purposes.

FIGURE 26. Three-phase 115-Vrms, Types II and III voltage spike test circuit configuration.



NOTE: Positive polarity Phase A-to-ground test circuit is shown for illustrative purposes.

FIGURE 27. Three-phase 440-Vrms, Types II and III voltage spike test circuit.

5.3.4 Emergency condition test. The emergency condition test shall be used to evaluate the user equipment performance under the following conditions:

a. Simulated automatic bus transfer test (70 msec power interruption and rapid re-application).

b. Simulated power interruption due to emergency power re-configuration test (2-minute power interruption and rapid re-application).

c. Simulated loss of steam to turbine generator (TG) test (power source voltage and frequency decay).

d. Simulated loss of generator voltage regulation test (voltage and frequency positive excursion).

5.3.4.1 Apparatus. The following apparatus is recommended for performing this test:

a. Power source of required capacity and range of voltage and frequency adjustments. A power source with a capability of having an independently programmable voltage and frequency output is recommended.

b. Voltmeters (true rms) - ±0.5 percent accuracy of reading.

c. Frequency meter - ±0.5 Hz accuracy of reading.

d. Storage oscilloscope having ≥ 500 kHz response per channel.

e. Current and potential transformers and probes as required.

f. Frequency to voltage transducer.

g. Temperature meter - ±0.5 °C accuracy.

5.3.4.2 Procedure. The user equipment shall be operated in a normal operating mode and with the power input voltage and frequency within the user tolerance envelopes as shown on Figures 9 through 15, as applicable, until the equipment temperatures have stabilized. Temperature stability shall be defined as when the variation between successive temperature measurements at the same location does not exceed 1 °C after 30 minutes.

5.3.4.2.1 70 msec power interruption test. The input power at nominal voltage and frequency shall be suddenly interrupted. After an interval no less than 70 msec, the input power shall be suddenly reapplied to nominal voltage and frequency. This cycle shall be repeated in all operating modes. Power source frequency, line voltage (one-phase), and line current shall be measured at the user equipment power input terminals and recorded before the start and during each cycle. Equipment designated as mission critical equipment by the PDA shall operate through the interruption without loss of data or a requirement for a manual restart. Inrush current surges observed during power interruption tests shall be addressed as described in 5.2.10.

5.3.4.2.2 2-Minute power interruption test. After the equipment has been operated long enough to detect any performance degradation and with the equipment in normal operating mode, the power to the user equipment shall be suddenly interrupted for an interval of 2 minutes followed by the sudden re-application of input power to the user equipment. This power interruption shall be accomplished by switching the power at the power source and not by using the power switch or equivalent at the user equipment. No manual interaction shall be allowed until the power is re-applied after the 2-minute interruption. This test shall be repeated in all operating modes. The user equipment is not required to sustain normal operation through the 2-minute power interruption; however, the unit shall be capable of returning to normal operation after power is suddenly re-applied at the end of the 2-minute interval. Inrush current surges observed during power interruption tests shall be addressed as described in 5.2.10.

5.3.4.2.3 Power source decay test. Following the power system interruption tests, the power source shall be modified as required to provide a voltage and frequency decay characteristic approximating that shown on Figure 8 for the "Half-load on Generator" curve. With the user equipment operating in one of the normal operating modes and with the power input voltage and frequency at nominal, initiate the power source output voltage and frequency decay characteristics specified above. The voltage and frequency shall follow the decay curves provided in Figure 8 extrapolated down to zero. If the test equipment source frequency does not extend down to zero, lower the frequency to the 50-percent value or lower and de-energize the test equipment source. At the end of the voltage and frequency decay transient, the power source output shall immediately return to nominal voltage and frequency. Line voltage, line current, and frequency shall be measured and recorded before the initiation of and during the power source decay test. The user equipment is not required to sustain operation during this test after the voltage and frequency go below the worst case envelopes as defined in Figures 9, 12, and 13. However, the unit shall be capable of returning to normal operation after power is suddenly re-applied at the end of the decay transient. Repeat the power source decay test for each operating mode.

5.3.4.2.4 Positive excursion test. Upon completion of the power source decay test, the user equipment shall be subjected to the emergency condition positive excursion tolerances specified in Table I, items 19 through 22, and duplicated in Table VI. The user equipment shall be operated in a normal mode with the power input voltage and frequency at nominal. The power input voltage shall be varied from nominal in accordance with the positive excursion limits and time duration specified in Table VI. At the end of the excursion duration, the power input voltage shall be immediately returned to nominal voltage. Then the power input frequency shall be varied from nominal in accordance with the positive excursion limits and time duration specified in Table VI. At the end of the excursion duration, the power input frequency shall be immediately returned to nominal frequency. Finally, the power input voltage and frequency shall be varied simultaneously from nominal in accordance with the positive excursion limits and time duration specified in Table VI. At the end of the excursion duration, the power input voltage and frequency shall be immediately returned to nominal voltage and frequency. Line voltage, one line current and frequency shall be measured and recorded before, during, and after each positive excursion test. Repeat the positive excursion test for each operating mode of the user equipment under test. Unless specified as Mission Critical Equipment (MCE) by the PDA and thereby required to operate through this test, the user equipment is not required to sustain operation during this test after the voltage and frequency go above the worst case envelopes as defined in Figures 9 through 15. However, the unit shall not be damaged and shall be capable of returning to normal operation when power is restored within the user tolerance envelope. MCE shall remain operational before, during, and after this test; the user equipment under test shall not experience any damage or operational interruption, suffer any loss of data, or require a restart or reboot.

TABLE VI. Emergency condition test.

Emergency Condition	Voltage Tolerance Percent of Nominal	Frequency Tolerance Percent of Nominal
Maximum Excursion: Duration - Type I power systems Duration - Type II power systems Duration - Type III power systems	+35 2 minutes 0.17 seconds 0.17 seconds	+12 2 minutes 0.17 seconds 0.17 seconds

5.3.5 Grounding test. For ungrounded systems, user equipment shall be tested for proper operation in each operating mode with one power input line grounded.

5.3.5.1 Apparatus. The following apparatus is recommended for performing this test:

a. Power source of required capacity and range of voltage and frequency adjustments. A power source with a capability of having an independently programmable voltage and frequency output is recommended.

b. Voltmeter (true rms) - ±0.5 percent accuracy.

c. Frequency meter - ±0.5 Hz accuracy.

d. Storage oscilloscope having ≥ 500 kHz response per channel.

e. Current and potential transformers and probes as required.

f. Three (for 3-phase) or two (for single phase) 100,000 ohm, 450 Vrms, 5W resistors.

g. Three (for 3-phase) or two (for single phase) single-pole fused switches or circuit breaker sized for the short circuit rating of the power supply.

5.3.5.2 Procedure. It is recommended that an isolated power source be used for this test to prevent grounding of commercial utility power lines. Each power input line shall be grounded through a 100,000-ohm resistor to the ground plane. The user equipment enclosure shall be grounded to the same ground plane. Each 100,000-ohm resistor shall have in parallel a single pole fused switch or circuit breaker of adequate rating. With the equipment operating in a normal operating mode and with voltage and frequency within the user tolerance envelope, close a switch and short one of the 100,000-ohm resistors. Leave the ground condition on for a sufficient period to determine any user equipment degradation, but at least for a minimum of 5 minutes, then remove the ground by opening the switch. Ground each power line in turn in the same manner. Repeat the test for each operating mode. Recordings of each input voltage shall be made for each test. The user equipment shall sustain normal operation throughout the grounding test.

5.3.6 User equipment power profile test. User equipment shall be tested to determine the following items in all operating modes. If the user equipment requires more than one input from the electric power system, the data shall be provided for each power input required. The power profile data shall include the applicable data listed below for each operating mode and shall be in accordance with the associated procedure.

a. Type of power (per 5.2.2).

b. Number of phases (per 5.2.2).

c. Voltage (rms) (per 5.2.2).

d. Line current magnitudes (rms).

e. Power factor (leading or lagging) (per 5.2.6).

f. Power kilowatt (kW) rated and typical operating power profile (per 5.2.2).

g. Surge/inrush current (per 5.2.10) - peak magnitude and duration.

h. Pulsed loading (per 5.2.7).

i. Load unbalance (per 5.2.5).

j. Spike generation.

k. Submarine Rigged for Reduced Electric (RRE) configuration power demand, where applicable.

l. Line-to-ground capacitance

m. Line-to-ground current

5.3.6.1 Apparatus. The following apparatus is recommended for performing this test:

a. Power source of required capacity and range of voltage and frequency adjustments. A power source with a capability of having an independently programmable voltage and frequency output is recommended.

b. Voltmeters (true rms) - ±0.5 percent accuracy.

c. Frequency meter - ±0.5 Hz accuracy.

d. Ammeters.

e. Power factor meter.

f. Storage oscilloscope having ≥ 500 kHz response per channel.

g. Current and potential transformers and probes as required.

5.3.6.2 Procedure. The user equipment shall be operated in accordance with the equipment operating procedure in one of the normal modes of operation. Power input voltage and frequency shall be within the user tolerance bands. Measure and record power input voltages (each phase), each line current, power factor for each phase, and power (kW). These measurements shall be made for each power input required from the electric power system. From the data collected during these tests, calculate and record the data elements specified in 5.3.6 for each user equipment power input. Surge/inrush current is discussed in 5.2.10 and limits are provided in Figures 21 and 22. The user equipment shall be de-energized and re-energized in accordance with the equipment operating procedures; surge/inrush current shall be measured, recorded, and evaluated when energizing the user equipment at the nominal input voltage for the following cases: when the voltage source sine-wave passes through 0 degrees (for inductive load equipment) and when the sine-wave passes through 90 degrees (for capacitive load equipment). The largest inrush current of the two cases shall be used. During this period of de-energizing and re-energizing, oscilloscope records shall be taken of one line voltage and each line current to determine surge/inrush current during the transition. The data recorded shall be of sufficient resolution to be able to accurately determine the magnitude and duration of the surge/inrush current. The power profile test shall be repeated for each normal operating mode and for each user equipment power input. All test values shall be within limits in accordance with the applicable requirements. The power source used for this test and its characteristics shall be reported in order to assist in analyzing the impact the equipment may have on a shipboard power system. The power source rating and its source impedance, as well as the length and type of connecting cable used, shall be included. Determine by measurement, calculation, or specification and record the value of the capacitance to ground for each power line of the user equipment. Line-to-ground capacitance limits are identified in 5.2.4. Determine by measurement, calculation, or specification and record the value of the line-to-ground current for each power line of the user equipment. Line-to-ground current limits are identified in 5.2.4.

5.3.7 Current waveform test. The harmonic content from nominal input line frequency up to 20 kHz of the current waveform in the user equipment power input lines shall be determined for each operating mode. The harmonic current of the user equipment shall be in compliance with the requirements in 5.2.9.

5.3.7.1 Apparatus. The following apparatus is recommended for performing this test:

a. Power source of required capacity and range of voltage and frequency adjustments. A power source with a capability of having an independently programmable voltage and frequency output is recommended.

b. Voltmeters (true rms) - ±0.5 percent accuracy.

c. Frequency meter - ±0.5 Hz accuracy.

d. Ammeters.

e. Wide-band current probe or shunt.

f. Current and potential transformers and probes as required.

g. Harmonic analyzer with a better than 3 percent of measured frequency band width below 2.5 kHz and a less than 75 Hz band width at frequencies between 2.5 and 200 kHz.

5.3.7.2 Procedure. The user equipment shall be energized in accordance with the equipment procedure and operated in a normal mode. The power source voltage and frequency shall be within the applicable frequency and voltage tolerance envelopes shown in Figures 9 through 15. The power input current harmonics shall be determined for each operating mode. The current harmonics shall be measured by means of a wide-band current probe or shunt in each power input line. The fundamental and harmonics of each line current shall be measured by means of a harmonic analyzer. The current harmonics shall be determined for each normal operating mode and shall not exceed the values specified in 5.2.9. If it is suspected that the power source has sufficient voltage harmonic distortion to affect current harmonic measurements, to determine the baseline harmonic currents due to the source, connect a linear load (no larger than the user equipment load and having the same fundamental frequency leading or lagging power factor as the user equipment to be tested) at the power interface where the user equipment would be connected. The harmonic currents shall be measured. These measured harmonic current values from the linear load may then be subtracted from the harmonic current values measured from the normally operated user equipment to provide an approximation of the equipment's harmonic current content.

5.3.8 Voltage and frequency modulation test. User equipment performance shall be evaluated under the voltage modulation and frequency modulation conditions specified in Table I, items 3 and 10, and further expanded in Table VII (see 3.3.3 and 3.4.4). The periodicity of voltage modulation should be considered to be longer than 1 cycle time at nominal frequency and less than 10 seconds. The periodicity of frequency modulation should be considered as not exceeding 10 seconds.

TABLE VII. Voltage and frequency modulation test.

	Voltage modulation				Frequency modulation			
	Limit (%)	**Nominal (Vrms)**	**Minimum (Vrms)**	**Maximum (Vrms)**	**Limit (%)**	**Nominal (Hz)**	**Minimum (Hz)**	**Maximum (Hz)**
Type I, 3-phase	2 2	115 440	112.70 431.20	117.30 448.80	0.5	60	59.7	60.3
Type I, 3-phase, grounded	2	200	196.00	204.00	0.5	60	59.7	60.3
Type I, 1-phase	2 2	115 440	112.70 431.20	117.30 448.80	0.5	60	59.7	60.3
Type I, 1-phase, grounded	2	115	112.70	117.30	0.5	60	59.7	60.3
Type II, 3-phase	2 2	115 440	112.70 431.20	117.30 448.80	0.5	400	398	402
Type II, 1-phase	2 2	115 440	112.70 431.20	117.30 448.80	0.5	400	398	402
Type III, 3-phase	1 1	115 440	113.85 435.60	116.50 444.40	0.5	400	398	402
Type III, 3-phase, grounded	1	200	198.00	202.00	0.5	400	398	402
Type III, 1-phase	1 1	115 440	113.85 435.60	116.15 444.40	0.5	400	398	402
Type III, 1-phase, grounded	1	115	113.85	116.15	0.5	400	398	402

5.3.8.1 Apparatus. The following apparatus is recommended for performing this test:

a. Power source of required capacity and range of voltage and frequency adjustments. A power source with a capability of having an independently programmable voltage and frequency output is recommended.

b. Voltmeters (true rms) - ±0.5 percent accuracy.

c. Frequency meter - ±0.5 Hz accuracy.

d. Storage oscilloscope having ≥ 500 kHz response per channel.

e. Current and potential transformers and probes as required.

f. Temperature meter - ±0.5 °C accuracy.

5.3.8.2 Procedure. The user equipment to be tested shall be operated in a normal operating mode within the user voltage and frequency tolerance band until the equipment temperatures have stabilized. Temperature stability shall be defined as when the variation between successive temperature measurements at the same location does not exceed 1 °C after 30 minutes. The voltage and frequency modulation test produces a voltage and frequency modulation on the input waveform from nominal to within the modulation limits defined by Table VII for the applicable power type. The input voltage and frequency shall be varied separately and then simultaneously. The input voltage (at least two phases for three-phase power equipment), input line current (at least two line currents for three-phase equipment), and frequency shall be recorded before initiation of modulating voltage and frequency and continue throughout each test run.

a. Voltage modulation test: With the frequency held constant at nominal, vary the voltage from minimum to maximum for periods of 17 msec, 75 msec, 250 msec, 500 msec, 1 second, 5 seconds, and 10 seconds. Repeat each cycle of modulation ten consecutive times before moving to the next modulation period, starting at 17 msec and ending at 10 seconds.

b. Frequency modulation test: With the voltage held constant at nominal, vary the frequency from minimum to maximum for periods of 17 msec, 75 msec, 250 msec, 500 msec, 1 second, 5 seconds, and 10 seconds. Repeat each cycle of modulation ten consecutive times before moving to the next modulation period, starting at 17 msec and ending at 10 seconds.

c. Combined voltage and frequency modulation test: Simultaneously vary the voltage from minimum to maximum and the frequency from minimum to maximum for periods of 17 msec, 75 msec, 250 msec, 500 msec, 1 second, 5 seconds, and 10 seconds. Repeat each cycle of modulation ten consecutive times before moving to the next modulation period, starting at 17 msec and ending at 10 seconds.

The user equipment shall operate normally with no operational degradation during all test conditions to show compliance with this test. The recording quality shall be sufficient to show that the proper modulation limits were conducted.

5.3.9 Simulated human body leakage current tests for personnel safety.

5.3.9.1 Apparatus. The following apparatus is recommended for performing this test:

a. Operational circuit configuration defined by Figure 28 for single-phase systems, by Figure 29 for single-phase systems derived from line-to-line of a three-phase wye and by Figure 30 for three phase systems.

b. Metering circuit defined by Figure 31 for low or high frequency operation.

c. Power source defined by the circuit configuration as either a single-phase center-tapped source or a three-phase wye source of required capacity determined by the Unit Under Test (UUT). The line voltage unbalance shall be less than 3 percent.

d. Voltmeter should be true rms of $\pm$0.5 percent accuracy; the frequency response should be within measurement requirements.

e. Insulated probe, such as an oscilloscope probe.

5.3.9.2 Procedure. With power disconnected, place the user equipment or UUT on an isolated surface. The UUT shall be isolated from any earth, power, or instrument ground. Single-phase user equipment shall be connected as in Figure 28 if it operates connected across one single-phase (line-to-line of a delta source or line-to-neutral of a wye source) of a three-phase transformer aboard ship. Alternately, single-phase user equipment shall be connected as in Figure 29 if it operates connected across two phases (line-to-line of a wye source) of a three-phase transformer aboard ship. Three-phase user equipment shall be connected as in Figure 30. The appropriate metering circuit shall be used for the intended frequency range, shown in Figure 31. Every mode of operation shall be tested. The current shall be determined by measuring the voltage drop across the metering circuit. The voltage measured across the metering circuit, when equal to 1.0 Vrms, represents 2.0 milliamperes of current. The overall measurement error shall not exceed 5 percent. Where there is risk for current paths to any control or external surface component, the insulated probe shall be used on all control or external surface components such as case, connector housings, recessed calibration or adjustment controls and control shafts with knobs removed.

5.3.9.2.1 Method of test.

WARNING: This test may be hazardous due to the ungrounded condition of the UUT during the test. Do not touch exposed metal surfaces.

a. Determine the applicable configuration from Figures 28, 29, or 30 for the UUT.

b. The power source shall be de-energized. Connect the UUT as in the applicable figure utilizing the low or high frequency metering circuit as required. Leave the power source unconnected.

c. Place the UUT ON-OFF switch in the OFF position.

d. Place the SAFETY GROUND switch in the CLOSED or GROUND position.

e. Connect and energize the power source.

f. Observe the WARNING. Place the SAFETY GROUND switch in the OPEN or UNGROUNDED position.

g. Place the UUT ON-OFF switch in the ON position.

h. Record the voltmeter reading.

i. Place the UUT ON-OFF switch in the OFF position.

j. Place the SAFETY GROUND switch in the CLOSED or GROUND position.

k. Repeat steps f through j for each and every mode of operation.

NOTES:

1. The safety ground conductor shall not carry load current.
2. Tests for delta loads shall use a wye power source providing balanced line-to-line open circuit voltages.

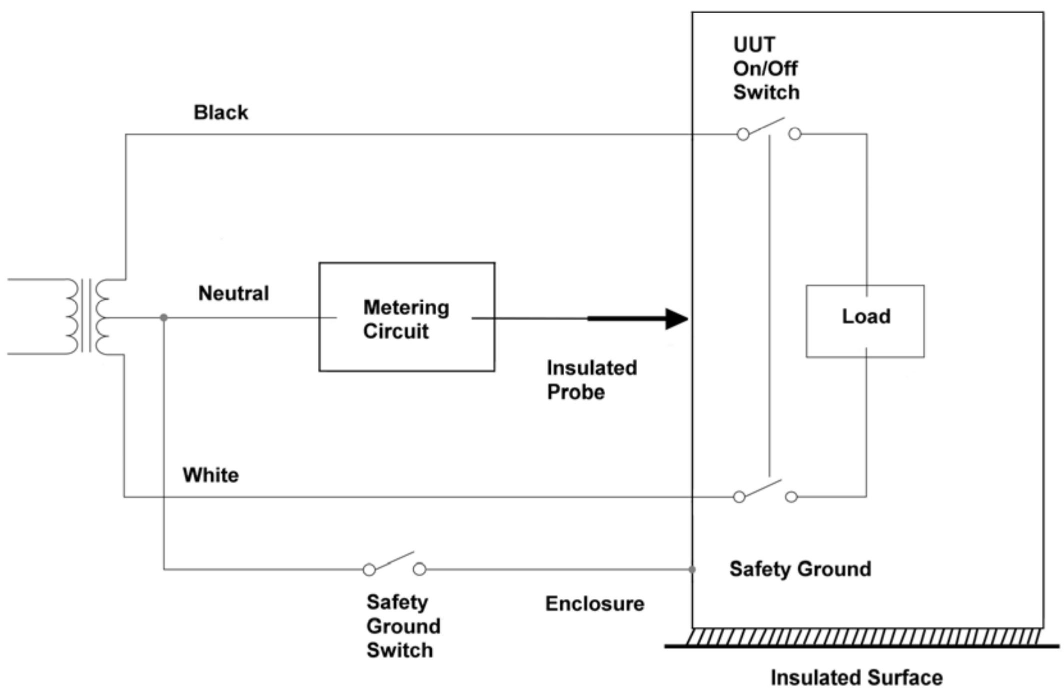


FIGURE 28. Single-phase simulated human body leakage current test setup if user equipment is connected to one single-phase source.

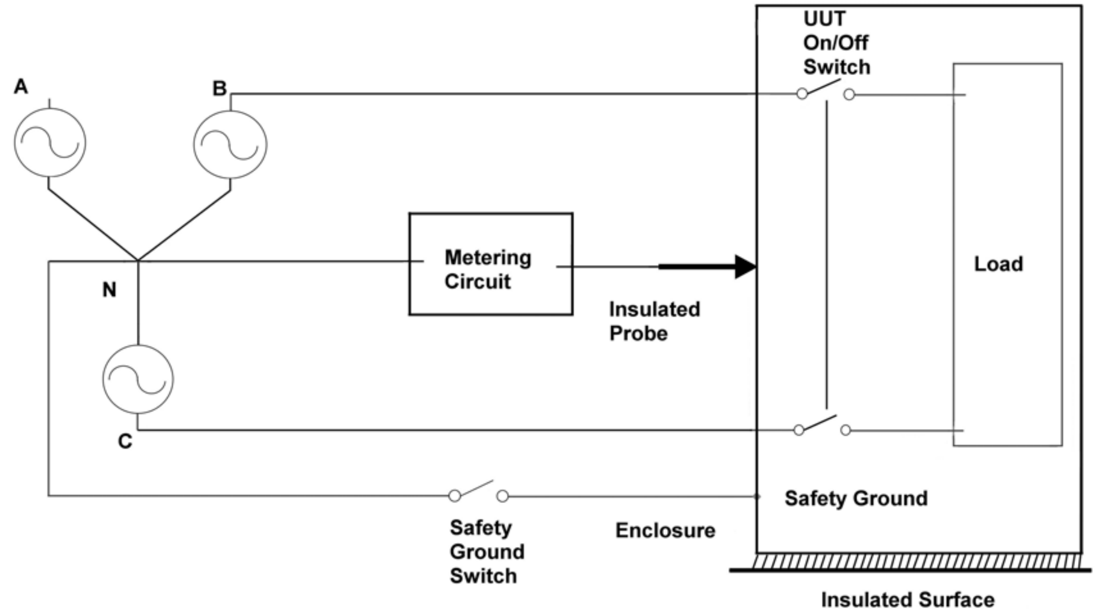


FIGURE 29. Single-phase simulated human body leakage current test setup if user equipment is connected to a single-phase of a three-phase source.

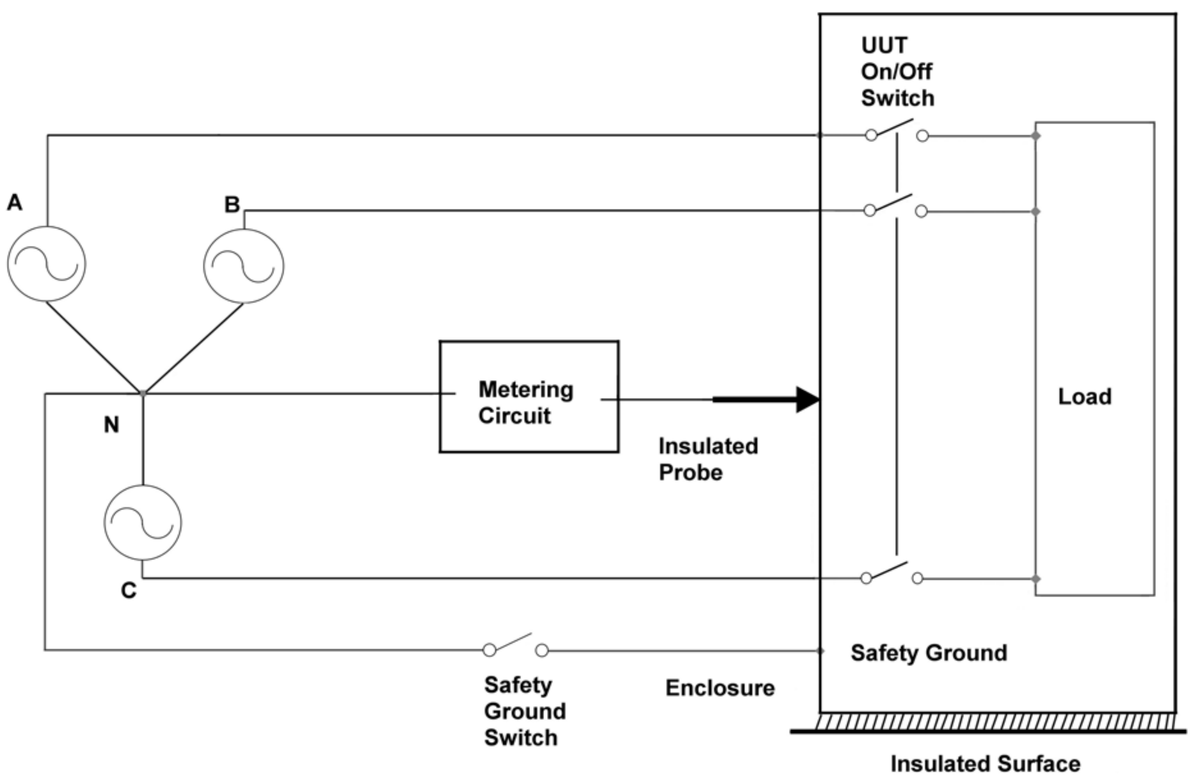


FIGURE 30. Three-phase simulated human body leakage current test setup for user equipment.

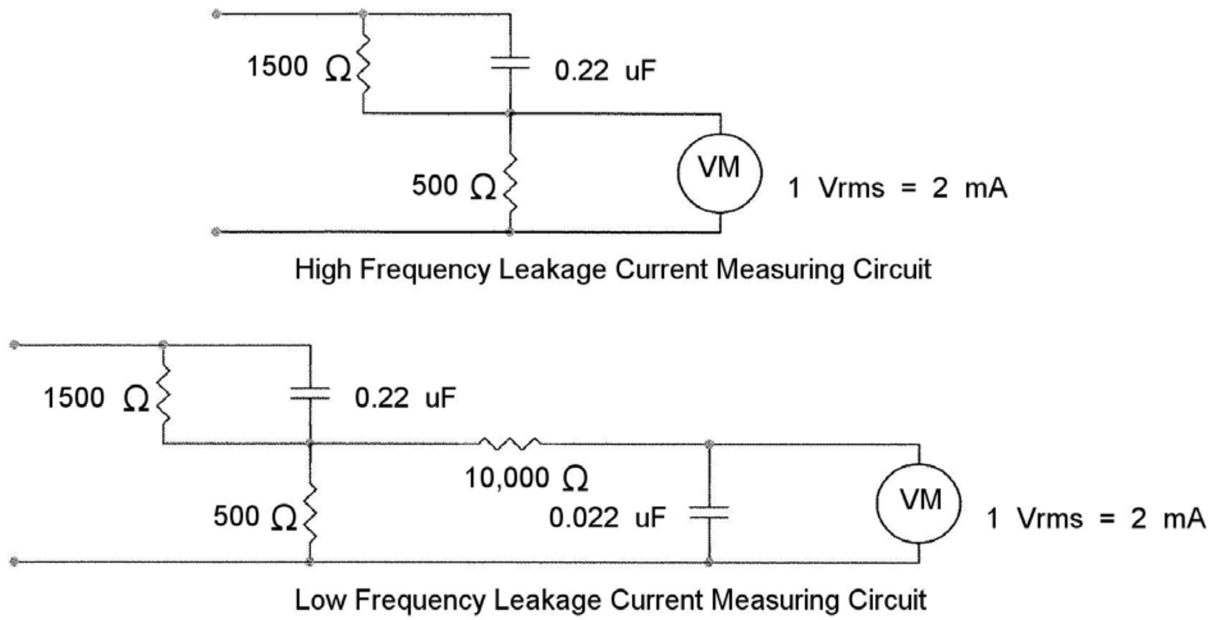


FIGURE 31. Metering circuits for high and low frequency simulated human body leakage current tests.

5.3.10 Equipment insulation resistance test. User equipment to be installed on ships shall be subjected to an insulation resistance test. User equipment to be installed on ships with an active ground detector shall also be subjected to an active ground detector test.

5.3.10.1 Insulation resistance test. With the power disconnected, use a megohmmeter insulation tester (megger) to conduct an insulation resistance test at a 500 VDC level. The test shall be conducted between each power conductor and ground for a minimum period of 60 seconds for each conductor. Ensure sensitive electronic components are disconnected from line-to-ground during this test. The user equipment shall tolerate the 500 VDC level without equipment damage, arc-over or degradation. The resistance to ground level as measured with the megohmmeter shall be equal to or greater than 10 Mohms (see 5.2.11).

5.3.10.2 Active ground detector (AGD) test. This test is conducted to determine the equipment tolerance to 150 VDC superimposed from line to ground on the 440 Vrms system or 50 VDC superimposed from line to ground on systems less than 440 Vrms. For three-phase user equipment, the UUT shall be connected to an isolated, ungrounded, three-phase transformer secondary source. For single-phase user equipment, the UUT shall be connected to an isolated, ungrounded, single phase transformer secondary source. With the UUT energized, the active ground detector test DC voltage shall be applied from one input line to ground for a minimum period of 3 minutes. Including worst case and added tolerance, for 150 VDC on 440 Vrms AGD systems, the test voltage shall be 440 Vrms x 1.414 x 1.200 + 155 VDC = 902 V; for 50 VDC on 115 Vrms AGD systems, the test voltage shall be 115 Vrms x 1.414 x 1.200 + 55 VDC = 250 V. The user equipment shall tolerate the combined AC and DC voltage stress without equipment damage, arc-over or degradation during this period. No abnormal operation of the user equipment during or after the test shall be permitted (see 5.2.12). For legacy AGDs, refer to 6.7.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard is intended to be used in designing surface ship and submarine AC electrical power systems and in designing and testing user equipment.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of the standard.

b. Report of results derived from tests listed in 5.3.

(1) Create test procedures by tailoring DI-EMCS-80201 so requirements 1 through 2.2; 2.4.a; 2.6.a, b, e, and f; and 2.7.b, c, and e are used, substituting “interface” for “EMI” and MIL-STD-1399-300 as the applicable military standard.

(2) Create a test report by tailoring DI-EMCS-80200 so requirements 1 through 2.2.a, b, f, g, i, m, o and 2.3 are used, substituting “interface” for “EMI” and MIL-STD-1399-300 as the applicable military standard.

c. Requirements for deviation requests (see 4.4 and 6.5).

6.3 Subject term (key word) listing.

Delta- and wye-connected systems

Frequency decay

Leakage current

Power factor

Transient limits

Worst case frequency excursion

6.4 International standardization agreement implementation. This standard implements STANAG 1008 Edition Number 8. When changes to, revision, or cancellation of this standard are proposed, the preparing activity must coordinate the action with the U.S. National Point of Contact for the international standardization agreement, as identified in the ASSIST database at http://assist.daps.dla.mil.

6.5 Deviation requests. Requests for deviation are to be submitted for approval to the Naval Sea Systems Command (NAVSEA 05Z3).

6.6 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

6.7 Automatic ground detection (AGD) legacy record. The present AGD voltage limits incorporated in Revision B have been reduced to eliminate the constant voltage stress on insulation systems throughout the electrical distribution systems and on line-to-ground components caused by the additive effect of the AGD and system voltages. AGD systems currently in the operating submarine fleet include 500 VDC on 440 Vrms and 150 VDC on 115 Vrms systems. (Concerning the 115 Vrms electric power system, only the aft 115 Vrms bus is exposed to the AGD system.) User equipment must tolerate the combined AC and DC voltage stress to ground without equipment damage, arc-over, or degradation.

a. For user equipment on the full-wave rectified, unfiltered, unregulated AGD systems aboard SSGN 726 Class, SSN 688 Class and SSN 21 Class ships, the user equipment should be tested for 3 minutes at the following voltages:

550 VDC on 440 Vrms AGD systems: 440 Vrms x 1.414 x 1.200 + 550 VDC x 1.571 x 1.200 = 1784 V

150 VDC on 115 Vrms AGD systems: 115 Vrms x 1.414 x 1.200 + 150 VDC x 1.571 x 1.200 = 478 V

b. For user equipment on the filtered, regulated AGD systems aboard SSN 774 Class ships, the user equipment should be tested for 3 minutes at the following voltages:

550 VDC on 440 Vrms AGD systems: 440 Vrms x 1.414 x 1.200 + 505 VDC = 1252 V

150 VDC on 115 Vrms AGD systems: 115 Vrms x 1.414 x 1.200 + 155 VDC = 350 V

Equipment and system manufacturers should be aware of the end use of their products to ensure that the design is capable of withstanding the AGD voltage levels associated with their end application.

Custodian:
Navy – SH

Review activities:
Navy – OS, YD

Preparing activity:
Navy – SH
(Project 1990-2008-001)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at http://assist.daps.dla.mil.