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DEPARTMENT OF DEFENSE INTERFACE STANDARD

AIRCRAFT ELECTRIC POWER CHARACTERISTICS

AMSC N/A **AREA SESS**

FOREWORD

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

2. The purpose of this interface standard is to ensure compatibility between the aircraft electric system, external power, and airborne utilization equipment.

3. Comments, suggestions, or questions on this document should be addressed to Commander, Naval Air Systems Command, Code 4.1.4, Highway 547, Lakehurst, NJ 08733-5100 or email to thomas.omara@navy.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at www.dodssp.daps.mil.

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1. SCOPE

1.1 Scope. This standard establishes the requirements and characteristics of aircraft electric power provided at the input terminals of electric utilization equipment. MIL-HDBK-704-1 through-8 defines test methods and procedures for determining airborne utilization equipment compliance with the electric power characteristics requirements defined herein. Electromagnetic interference and voltage spikes are not covered by this standard.

2. APPLICABLE DOCUMENTS

2.1 General. The document listed in this section is specified in sections 3, 4, and 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 documents cited in sections 3, 4, and 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.

INTERNATIONAL STANDARDIZATION AGREEMENTS

STANAG 3456 Aircraft Electrical System Characteristics

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

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 standard takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Acronyms used in this standard. The acronyms used in this standard are defined as follows:

a. AC – Alternating Current
b. COTS – Commercial Off-The-Shelf
c. DC – Direct Current
d. DoD – Department of Defense
e. kVA – kilovolt-ampere

f. NATO – North Atlantic Treaty Organization
g. POR – Point of Regulation
h. RMS – Root Mean Square
i. STANAG – Standardization Agreement
j. VA – Volt-ampere

3.2 Abnormal operation. Abnormal operation occurs when a malfunction or failure in the electric system has taken place and the protective devices of the system are operating to remove the malfunction or failure from the remainder of the system before the limits for abnormal operation are exceeded. The power source may operate in a degraded mode on a continuous basis where the power characteristics supplied to the utilization equipment exceed normal operation limits but remain within the limits for abnormal operation.

3.3 AC voltage. AC voltage is the root mean square (RMS) phase to neutral value for each half cycle.

a. Steady state AC voltage is the time average of the RMS voltage over a period not to exceed one second.

b. Peak AC voltage is the maximum absolute value of the instantaneous voltage.

c. The direct current (DC) component of the AC voltage is the average value of the voltage.

3.4 Aircraft electric power systems. An aircraft electric power system consists of a main power source, emergency power source, power conversion equipment, control and protection devices, and an interconnection network (wires, cables, connectors, etc.). The main power is derived from aircraft generators driven by the aircraft propulsion engines. Emergency power is derived from batteries, engine bleed air, independent auxiliary power units, ram air driven generators, or hydraulically driven generators.

3.5 Crest factor. The crest factor is the absolute value of the ratio of the peak to the RMS value for each half cycle of the voltage waveform.

3.6 Current. Alternating Current (AC) current is the RMS value for one half cycle measured between consecutive zero crossings of the fundamental frequency component. Direct Current (DC) current is the instantaneous value.

3.7 Current modulation. Current modulation is the difference between maximum current and minimum current. Percent current modulation is the ratio of the current modulation to the average (mean for DC, RMS of the fundamental for AC) current multiplied by 100 over a one second period.

3.8 DC voltage. Steady state DC voltage is the time average of the instantaneous DC voltage over a period not to exceed one second.

3.9 Distortion. AC distortion is the RMS value of the AC waveform exclusive of the fundamental. In a DC system, DC distortion is the RMS value of the alternating voltage component on the DC voltage.

3.10 Distortion factor. The AC distortion factor is the ratio of the AC distortion to the RMS value of the fundamental component. The DC distortion factor is the ratio of the DC distortion to the DC steady state voltage.

3.11 Distortion spectrum. The distortion spectrum quantifies AC or DC distortion in terms of the amplitude of each frequency component. The distortion spectrum includes the components resulting from amplitude and frequency modulation as well as harmonic and non-harmonic components of the waveform.

3.12 Electric starting operation. Electric starting operation is a specialized case of normal electric system operating conditions where the normal voltage limits may be exceeded due to the high electric demand. The voltage limits for normal operation may be exceeded during the following starting conditions:

a. An electric start of the propulsion engine. (Battery power, aircraft DC power or external power applied on the aircraft bus.)

b. A battery start of an auxiliary power unit.

3.13 Emergency operation. Emergency operation occurs following the loss of the main generating equipment when a limited electric source, independent of the main system, is used to power a reduced complement of distribution and utilization equipment selected to maintain flight and personnel safety.

3.14 External power source. The external power source refers to the ground or shipboard power source used to provide power to the aircraft's electrical distribution system.

3.15 Frequency. Frequency is the reciprocal of the period of the AC voltage waveform. The unit of frequency is Hertz (Hz). Steady state frequency is the time average of the frequency over a period not to exceed one second.

3.16 Frequency modulation. Frequency modulation is the difference between the maximum and minimum frequency values that occur in a one-minute period during steady state operating conditions. Frequency modulation is a measure of the stability of the power system's frequency regulation.

3.17 Load unbalance. Load unbalance for a three-phase load is the difference between the highest and lowest phase loads.

3.18 Normal operation. Normal operation occurs when the system is operating as intended in the absence of any fault or malfunction that degrades performance beyond established requirements. It includes all system functions required for aircraft operation except during the electric starting of propulsion engines and the battery start of an auxiliary power unit. Normal operation includes switching of utilization equipment, prime mover speed changes, synchronizing and paralleling of power sources, and operation from external power sources.

Transfer operation, as defined herein, is a normal function. It is treated separately in this standard because of the power interruption that it may produce.

Conducted switching spikes, which are excursions of the instantaneous voltage not exceeding 50 microseconds, are normal operation characteristics.

3.19 Overfrequency and underfrequency. Overfrequency and underfrequency are those frequencies that exceed the limits for normal operation and are limited by the action of protective devices.

3.20 Overvoltage and undervoltage. Overvoltage and undervoltage are those voltages that exceed the limits for normal operation and are limited by the action of protective devices.

3.21 Point of regulation. The POR is that point at which a power generation source senses and regulates the system voltage. The POR should be at the input terminals of the line contactor connecting the power source to the load bus.

3.22 Power factor. The ratio of real power (measured in watts) to apparent power (measured in volt-amperes).

3.23 Pulsed load. Pulsed loads are loads whose power requirement varies under steady state conditions because of underlying physical phenomena or the inherent operating mode of equipment.

3.24 Rate of change of frequency. The rate of change of frequency is defined as the ratio of the absolute difference in frequency over a designated period of time to the designated period of time. The unit of rate of change of frequency is designated Hertz per second (Hz/s).

3.25 Ripple. Ripple is the variation of voltage about the steady state DC voltage during steady state electric system operation. Sources of ripple may include, but are not limited to, voltage regulation instability of the DC power source, commutation/rectification within the DC power source, and load variations within utilization equipment.

Ripple amplitude is the maximum absolute value of the difference between the steady state and the instantaneous DC voltage.

3.26 Steady state. Steady state is that condition in which the characteristics remain within the limits for normal operation steady state characteristics throughout an arbitrarily long period of time. Steady state conditions may include lesser transients.

3.27 Transfer operation. Transfer operation occurs when the electric system transfers between power sources, including transfers from or to external power sources.

3.28 Transient. A transient is a changing value of a characteristic that usually occurs as a result of normal disturbances such as electric load change and engine speed change. A transient may also occur as a result of a momentary power interruption or an abnormal disturbance such as fault clearing.

a. Transients that do not exceed the steady state limits are defined as lesser transients.

b. Transients that exceed the steady state limits but remain within the specified normal transients limits are defined as normal transients.

c. Transients that exceed normal transients limits as a result of an abnormal disturbance and eventually return to steady state limits are defined as abnormal transients.

3.29 Utilization equipment. Utilization equipment is that equipment which receives power from the electric power system.

3.30 Utilization equipment terminals. Utilization equipment terminals provide the interface with the electric power system. Power interconnections, within the utilization equipment or equipment system, are excluded.

3.31 Voltage modulation. Voltage modulation is the variation of AC voltage during steady state AC electric system operation. Sources of voltage modulation may include, but are not limited to, voltage regulation stability of the AC power source, generator speed variations, and load variations within utilization equipment. Voltage modulation amplitude is the difference between the maximum and minimum AC voltage values that occur in a one second period during steady state operating conditions.

3.32 Voltage phase difference. The voltage phase difference is the difference in electrical degrees between the fundamental components of any two-phase voltages taken at consecutive zero crossings traced in the negative to positive direction.

3.33 Voltage unbalance. Voltage unbalance is defined as the maximum difference between RMS phase voltage amplitudes at the utilization equipment terminals.

4. GENERAL REQUIREMENTS

4.1 Aircraft electric power system requirements.

4.1.1 Aircraft electric power system performance. The aircraft electric power system shall provide electric power having the characteristics specified in this standard at the utilization equipment terminals during all operations of the power system.

4.1.2 Electrical power source characteristics. The characteristics of the electrical power measured at the output terminals of an unregulated power source or the POR of a regulated power source shall be within the limits specified in the applicable detail specification of the power source. It is the responsibility of the airframe manufacturer or modifier to provide the distribution and protection network to the terminals of the utilization equipment while maintaining the power characteristics specified in this standard.

4.1.3 Protective devices. Protective devices shall function independently of control and regulation equipment.

4.2 Aircraft utilization equipment requirements.

4.2.1 Power compatibility. Utilization equipment shall be compatible with the power characteristics specified herein. Utilization equipment shall not require electric power of better quality than specified herein. Utilization equipment shall be compatible with the applicable aircraft specification requirements for control of electromagnetic interference and voltage spikes induced by lightning, electromagnetic pulses, and power switching. Electromagnetic interference and voltage spikes are not covered by this standard.

4.2.2 Operation. When supplied electric power having characteristics specified herein, aircraft utilization equipment shall provide the level of performance required by its detail specification for each operating condition. Operation of utilization equipment shall not cause the power characteristics at its terminals to exceed the limits specified herein. Utilization equipment operation under any electric system operating condition shall not have an adverse effect on or cause malfunction of the electric system.

4.2.2.1 Normal operation. Utilization equipment shall provide the level of performance specified in its detail specification.

4.2.2.2 Abnormal operation. Utilization equipment shall be permitted a degradation or loss of function unless otherwise specified in its detail specification. Utilization equipment shall not suffer damage or cause an unsafe condition. Utilization equipment shall automatically resume full performance when normal operation of the electrical system is restored.

4.2.2.3 Transfer operation. Utilization equipment may not be required to operate under the transfer condition unless a level of performance is specified by its detail specification. Utilization equipment shall automatically resume specified performance when normal operating characteristics are resumed.

4.2.2.4 Emergency operation. Utilization equipment shall provide the level of performance specified in its detail specification when such performance is essential for flight or safety.

4.2.2.5 Starting operation. Utilization equipment shall provide the level of performance specified in its detail specification when performance is essential during the starting operation.

4.2.3 Power failure. The loss of power (AC or DC) or the loss of one or more phases of AC power to any utilization equipment terminal shall not result in an unsafe condition or damage to utilization equipment.

4.2.4 AC power utilization. Utilization equipment that requires more than 0.5 kVA of AC power shall be configured to utilize three-phase steady state balanced power. Load unbalance of individual utilization equipment shall be within the limits of figure 1. The load unbalance of utilization equipment whose total load is greater than 30 kVA shall be no greater than 3.33 percent of its total three-phase load. Single-phase AC power shall be used only on a line-to-neutral basis. AC power shall not be half-wave rectified.

4.3 External power source requirement. External electric power sources shall supply power having the characteristics specified in this standard at the power input terminals of the aircraft electric utilization equipment. In order to allow for steady state voltage drop between the aircraft external power receptacle and the aircraft utilization equipment terminals, the voltage at the external power receptacle shall be as follows:

a. AC system 113 to 118 volts (AC voltage drop of 0 to 5 volts)
b. 28 VDC system 24 to 29 volts (DC voltage drop of 0 to 2 volts)
c. 270 VDC system 260 to 280 volts (DC voltage drop of 0 to 10 volts)

4.4 Test requirements. Equipment testing is required to demonstrate utilization equipment compatibility with the electric power characteristics of this standard. Utilization equipment test requirements shall be in accordance with the equipment detail specification. The applicable test methods of MIL-HDBK-704 shall be used to determine that the utilization equipment complies with this standard. Aircraft shall be tested to demonstrate that the aircraft electric system power characteristics are within the limits of this standard throughout all operating conditions of the aircraft and its utilization equipment. Aircraft test requirements shall be in accordance with the aircraft detail specification.

5. DETAILED REQUIREMENTS

5.1 Transfer operation characteristics. Under conditions of bus or power source transfers, voltage and frequency shall not vary between zero and normal operating limits for longer than 50 milliseconds. A normal transient may occur upon completion of a transfer.

5.2 AC power characteristics.

5.2.1 Type system. AC systems shall provide electrical power using single-phase or three-phase wire-connected grounded neutral systems. The voltage waveform shall be a sine wave with a nominal voltage of 115/200 volts and a nominal frequency of 400 Hz. Variable frequency and double-voltage systems may be used as alternative electrical power systems. Variable frequency systems have frequencies varying from 360 to 800 Hz with a nominal voltage of 115/200 volts. Double-voltage systems have nominal voltages of 230/400 volts and a nominal frequency of 400 Hz. A third alternative for secondary electric power systems is single-phase 60

Hz systems. These systems have a nominal voltage of 115 volts with a nominal frequency of 60 Hz and are used in support of COTS equipment only.

All power types may not be available on all aircraft platforms. The selection of the input power type for utilization equipment shall take into consideration the aircraft power types available on the intended platform and the capacity of the electrical system of that aircraft platform.

5.2.2 Phase sequence. The phase sequence shall be A-B-C and aircraft wiring and equipment terminals shall be marked accordingly. Generator terminals shall be marked T1-T2-T3 corresponding to A-B-C, respectively. The phase sequence shall be counterclockwise (positive) as shown on figure 2.

5.2.3 Normal operation. Normal operation characteristics shall be in accordance with figures 3, 5, and 7, table I for 400 Hz systems and table II for variable frequency systems; and figures 8, 10 and 12, and table III for 60 Hz systems.

For variable frequency systems the rate of change of frequency from onset of a normal frequency transient measured for over a period of time of greater than 25 milliseconds shall not exceed 250 Hz per second.

5.2.4 Abnormal operation. The overvoltage and undervoltage values shall be within the limits of figure 4 for 400 Hz and variable frequency systems and figure 9 for 60 Hz systems. The overfrequency and underfrequency values shall be within the limits of figure 6 for 400 Hz systems, and figure 11 for 60 Hz systems. The overfrequency and underfrequency for variable frequency systems shall not exceed the 360 - 800 Hz steady state values.

For variable frequency systems the rate of change of frequency from onset of an abnormal frequency transient measured for over a period of time of greater than 25 milliseconds shall not exceed 500 Hz per second.

5.2.5 Emergency operation. All power characteristics in emergency operation shall be the same as normal operation.

5.3 DC power characteristics.

5.3.1 Type system. DC systems shall provide power using direct current, two-wire or negative ground return system having a nominal voltage of 28 Volts or 270 Volts. These systems shall conform to figures 13, 14, 15, 16, 17, 18 and table IV.

5.3.2 28 volts DC system.

5.3.2.1 Normal operation. Normal operation characteristics shall be in accordance with figures 13, 15 and table IV.

5.3.2.2 Abnormal operation. Overvoltage and undervoltage values shall be within the limits of figure 14.

5.3.2.3 Emergency operation. The DC steady state voltage in emergency operation shall be between 16 and 29 volts.

5.3.2.4 Electric starting. The DC voltage in electric starting operation shall be between 12 and 29 volts. Electric starting of an auxiliary power unit (other than battery starts) is a normal operating function and is not included under this condition.

5.3.3 270 volts DC system.

5.3.3.1 Normal operation. Normal operation characteristics shall be in accordance with figures 16 and 18 and table IV.

5.3.3.2 Abnormal operation. Overvoltage and undervoltage values shall be within the limits of figure 17.

5.3.3.3 Emergency operation. All power characteristics in emergency operation shall be the same as normal operation.

5.4 Load characteristics.

5.4.1 Grounding. All electrical power input terminals, including AC neutral and DC negative terminals, shall be electrically isolated from case ground. Equipment chassis shall not be used for power returns.

5.4.2 Load unbalance. Load unbalance of three-phase AC equipment shall be in accordance with figure 1. Load unbalance of equipment exceeding 30 kVA shall not exceed 3.33 percent of the total three-phase load.

5.4.3 Power factor. Power factor of AC equipment greater than 500 VA shall be between 0.85 lagging and unity when operating at 50 percent or more of its rated load current in steady state condition. AC equipment shall not have leading power factor when operating at more than 100 VA.

5.4.4 Polarity or phase reversal. Three-phase AC equipment shall not be damaged by reversal of input phase sequence. Single-phase AC equipment shall not be damaged by reversal of line and neutral connections. DC equipment shall not be damaged by reversal of positive and negative connections. Employing a positive physical means to prevent phase or polarity reversal shall also fulfill this requirement.

5.4.5 Multiple input terminals. Equipment having multiple input terminals for connection to more than one power source shall isolate the inputs from each other so that one power source cannot supply power to another. AC inputs shall not be paralleled. DC inputs shall be protected with blocking diodes if they are paralleled.

6. NOTES

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

6.1 Intended use. The intent of this document is to define the electric power quality requirements for DoD aircraft, however it may also be used with commercial aircraft or other types of vehicles. Other industry documents such as SAE-AS1212 and ISO 1540 also define aircraft electric power quality requirements. These documents are generally not appropriate for use with military aircraft because they do not address all of the areas of concern with military aircraft electric power quality and often require wider limits compared to this document due to the differences in the types and sizes of aircraft covered. In addition, they do not always take into account legacy DoD aircraft electrical power systems or legacy DoD utilization equipment. The power characteristics requirements of this document also apply to commercial and non-developmental utilization equipment purchased in accordance with the policy described in the SD-2, “Buying Commercial & Nondevelopmental Items: A Handbook”. If such equipment does not fully comply with the power characteristics requirement of this document, the effect of the equipment noncompliance on the electrical power quality and on the equipment capability to perform its intended function in the aircraft should be evaluated.

6.2 Considerations. Each element of the aircraft electrical power system is qualified and purchased to its own specification requirements document. The requirements of this document are less severe than the output power requirements of the typical electrical power source, taking into account the degradation of electrical power quality that can occur between a power source and the input electrical power terminals of utilization equipment. The effects of the electrical power distribution, control, and protection system, and the interactions between electrical power sources and utilization equipment may cause the degradation of electrical power quality.

6.3 Supersession data. This edition of MIL-STD-704 supersedes all previous editions. Previous editions of MIL-STD-704, which are cited in contracts for legacy aircraft electrical systems remain in effect for procurement of utilization equipment. Therefore, copies of previous editions should be retained, as they are no longer stocked by the Government.

6.4 International standardization implementation. This standard implements STANAG 3456, “Aircraft Electrical System Characteristics”. 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 www.dodssp.daps.mil.

6.5 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.

6.6 Application of this standard in utilization equipment specifications. Utilization equipment specifications should include a statement that "This equipment shall utilize electric power in accordance with MIL-STD-704 and shall be in accordance with the utilization equipment requirements of MIL-STD-704." The equipment specification should also specify the type of electric power to be utilized and the detailed performance required during normal, abnormal, emergency, starting, transfer and power failure operation of the electric system. The electric power characteristics specified herein are minimum requirements for utilization equipment. Therefore, specifications for utilization equipment that require greater operating margins should include specific electric power characteristic operating ranges that exceed those stated herein. Utilization equipment specifications should never specify operating ranges that are narrower than those specified herein nor waive compatibility with the electric power characteristics specified herein, since that could result in failure of the equipment to perform as required. Utilization equipment specifications should also include requirements that reduce the likelihood of the equipment having an adverse effect on the electric power characteristics provided by the electric system. High inrush current, low lagging power factor, high peak power to average power ratio, high current ripple amplitude, and current distortion are some characteristics of utilization equipment that can adversely affect the electric system by degrading electric power characteristics or increasing capacity requirements. Minimizing these undesirable utilization equipment characteristics involves tradeoffs with weight, cost and reliability that are specific to each type of equipment and should be addressed in the utilization equipment specification.

6.7 Pulsed load design issues. Pulsed loads are a potential cause of unacceptable voltage modulation. Hence large pulsed loads may require excess power source capacity or dedicated power sources to protect other aircraft equipment. The utilization equipment designer should strive to minimize the current modulation produced by pulsed loads.

6.8 Non-linear loads and effects. Attention must be given to non-linear loads and their effect on the AC power bus. All loads should not introduce excessive current distortion such that other equipment is affected.

6.9 Precedence. Tables and equations included in the figures take precedence over the graphical representation of the figure itself. Continuous reproduction of the figures may result in the distortion of the curves.

6.10 Guidance and lessons learned.

6.10.1 Compatibility and testing. Historically users of MIL-STD-704 interpret or view the electrical power quality characteristics limits in this document as they would those of a typical power source/generator. This interpretation is incorrect. An aircraft electrical system is composed of a variety of power components (generation, conversion, inversion, control, power distribution, power management devices, etc.) that provide power to aircraft buses and utilization equipment terminals. Each component and subsystem is designed and tested to its individual equipment specification, which often requires tighter performance than does MIL-STD-704 to compensate for the effects of loads as well as the associated feeder/line voltage drops therein. Therefore, the limits specified herein are minimum requirements for specifying that utilization equipment is compatible with aircraft electrical power. To ensure utilization equipment is compatible with the aircraft power, system testing as outlined in MIL-HDBK-704-1 through -8 should be performed. For information and access to the MIL-STD-704 compatibility test laboratory and test methods of MIL-HDBK-704-1 through -8, please contact:

Naval Air Systems Command
Attn: MIL-STD-704 Laboratory
Electrical Power Systems Division (AIR-4.4.4)
48298 Shaw Road, Bldg. 1461
Patuxent River, MD 20670
Website: http://ppe.navair.navy.mil/

6.10.2 Compatibility and installation. Users of MIL-STD-704 power should consider selection and installation processes when planning to integrate and install utilization equipment or components in aircraft. System designers should be aware of the related interface standards, MIL-STD-7080, MIL-STD-464 and SAE-AS50881, which address installation, electromagnetic compatibility and wiring, respectively. Use of these standards is recommended, especially when incorporating COTS equipment into military aircraft. The 60 Hz power requirements were included to accommodate COTS and non-developmental items procured using procedures of SD-2. Equipment designed for use on military aircraft should not use 60 Hz power, since it requires more weight and prime mover capacity per unit of power consumed by the utilization equipment.

6.11 Subject term (keyword) listing.

AC power utilization
DC voltage
Electric starting operation
Equipment, utilization
Power compatibility
System, electrical
Voltage

TABLE I. AC normal operation characteristics - 400 Hertz (see 5.2.3).

Steady state characteristics	Limits
Steady state voltage	108.0 to 118.0 Volts, RMS
Voltage unbalance	3.0 Volts, RMS maximum
Voltage modulation	2.5 Volts, RMS maximum
Voltage phase difference	116° to 124°
Distortion factor	0.05 maximum
Distortion spectrum	Figure 7
Crest factor	1.31 to 1.51
DC component	+ 0.10 to - 0.10 Volts
Steady state frequency	393 to 407 Hz
Frequency modulation	4 Hz
Transient characteristics	**Limits**
Peak voltage	±271.8 Volts
Voltage transient	Figure 3
Frequency transient	Figure 5

TABLE II. AC normal operation characteristics - variable frequency (see 5.2.3).

Steady state characteristics	Limits
Steady state voltage	108.0 to 118.0 Volts, RMS
Voltage unbalance	3.0 Volts, RMS maximum
Voltage modulation	2.5 Volts, RMS maximum
Voltage phase difference	116° to 124°
Distortion factor	0.05 maximum
Distortion spectrum	Figure 7
Crest factor	1.31 to 1.51
DC component	+0.10 to – 0.10 Volts
Steady state frequency	360 to 800 Hz
Frequency modulation	4 Hz
Transient characteristics	**Limits**
Peak voltage	±271.8 Volts
Voltage transient	Figure 3
Frequency transient	Not to exceed steady state values of 360 to 800 Hz
Maximum rate of change of frequency	250 Hz/sec

TABLE III. AC normal operation characteristics - 60 Hertz (see 5.2.3).

Steady state characteristics	Limits
Steady state voltage Voltage unbalance Voltage modulation Voltage phase difference Distortion factor Distortion spectrum Crest factor DC component Steady state frequency Frequency modulation	105.0 to 125.0 Volts, RMS 3.0 Volts, RMS maximum 2.5 Volts, RMS maximum 116° to 124° 0.05 maximum Figure 12 1.31 to 1.51 +0.10 to – 0.10 Volts 59.5 to 60.5 Hz 0.5 Hz
Transient characteristics	Limits
Peak voltage Voltage transient Frequency transient	±271.8 Volts Figure 8 Figure 10

TABLE IV. DC normal operation characteristics (see 5.3.2.1, 5.3.4.1).

Steady state characteristics	Limits	
	28 Volt DC system	270 Volt DC system
Steady state voltage Distortion factor Distortion spectrum Ripple amplitude	22.0 to 29.0 Volts 0.035 maximum Figure 15 1.5 Volts maximum	250.0 to 280.0 Volts 0.015 maximum Figure 18 6.0 Volts maximum
	Limits	
Transient characteristics	28 Volts DC system	270 Volts DC system
Voltage transient	Figure 13	Figure 16

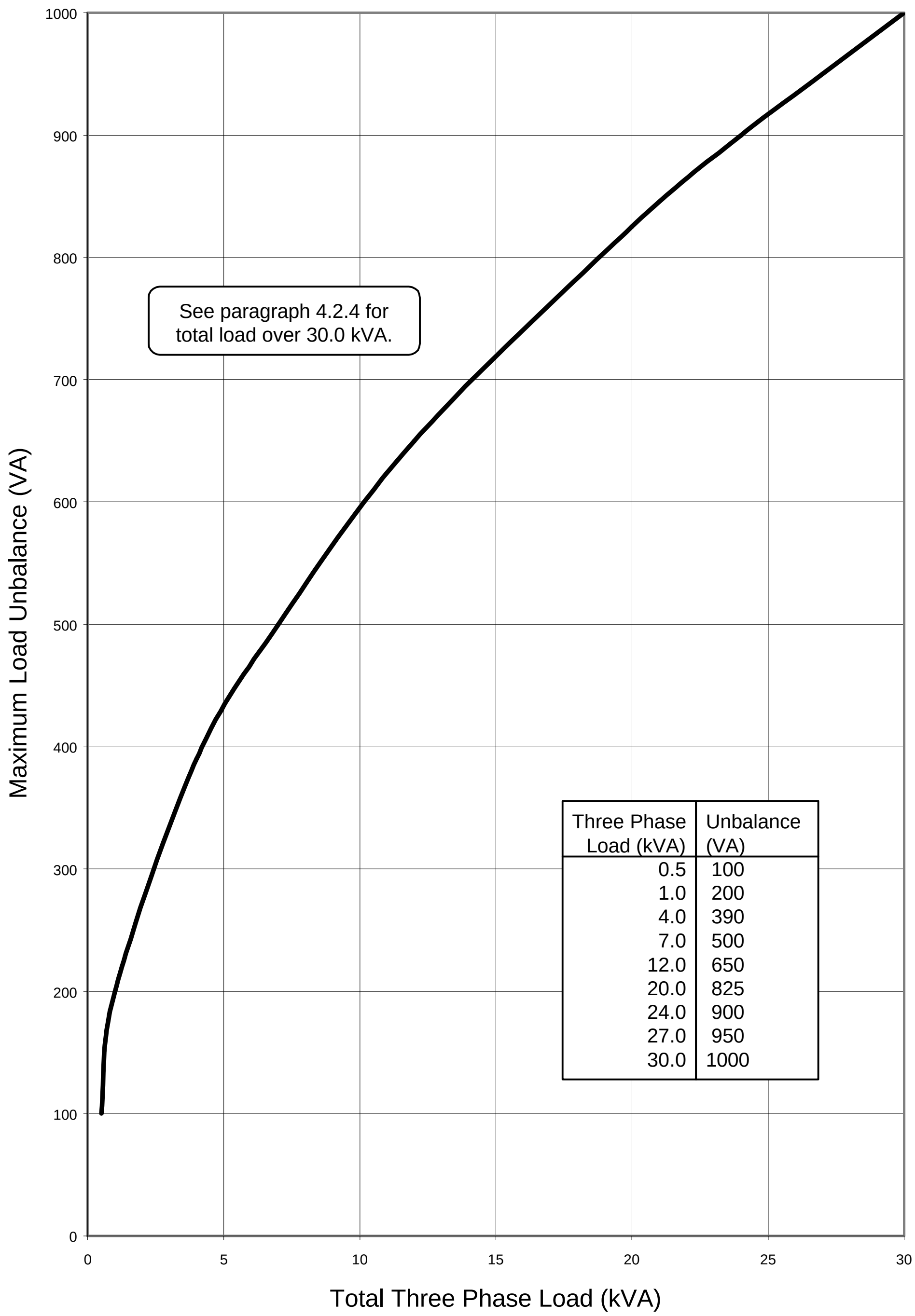


FIGURE 1. <u>Load unbalance limits for three-phase utilization equipment</u>.

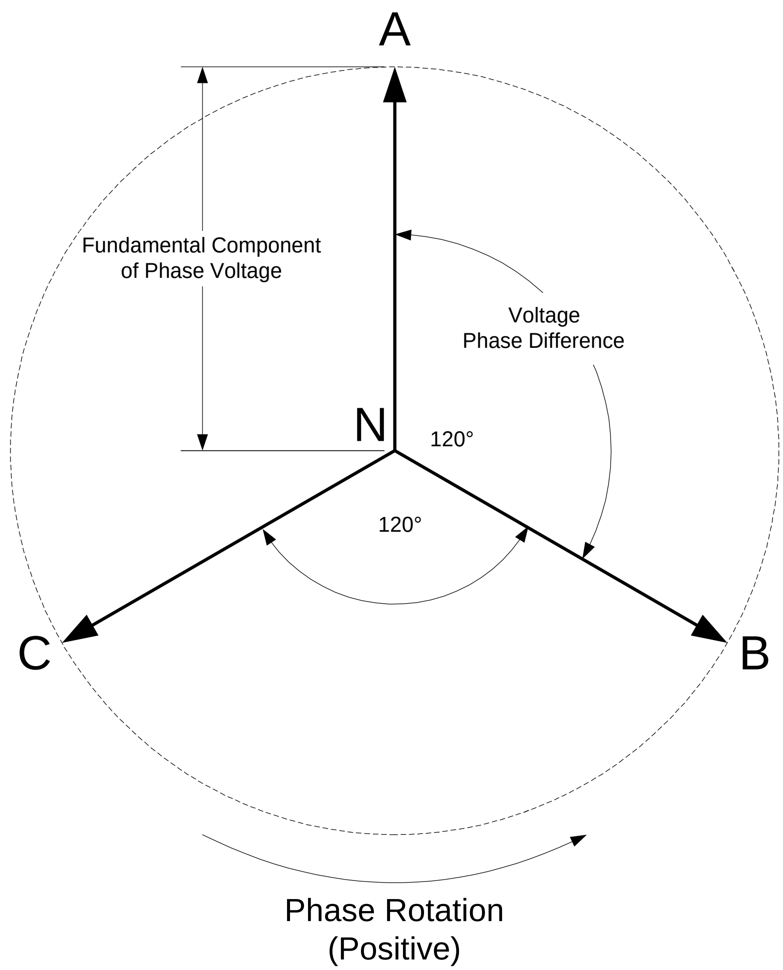


FIGURE 2. Phasor diagram showing required phase sequence relationship.

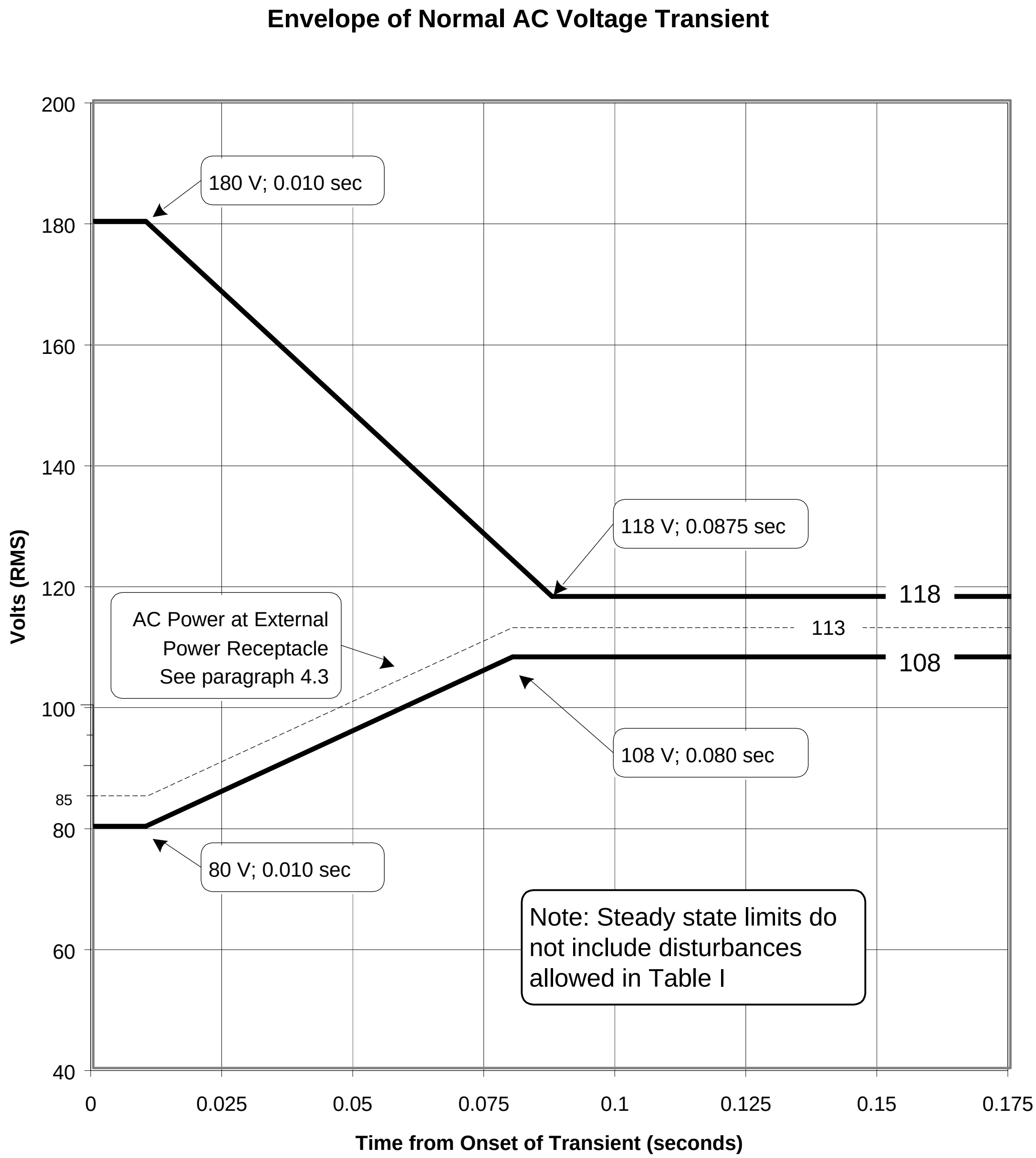


FIGURE 3. Envelope of normal 400 Hz and variable frequency AC voltage transient.

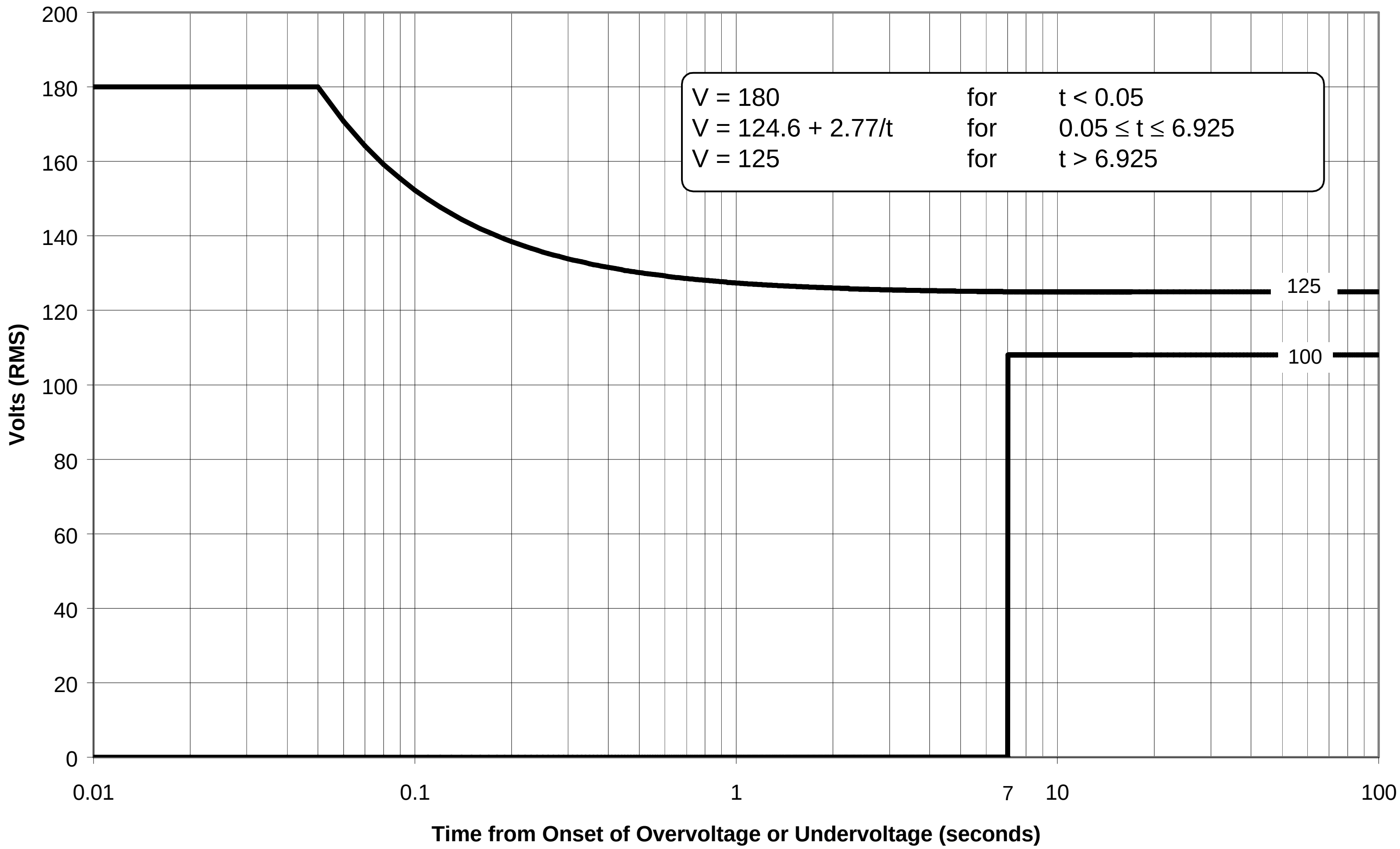


FIGURE 4. Limits for 400 Hz and variable frequency AC overvoltage or undervoltage.

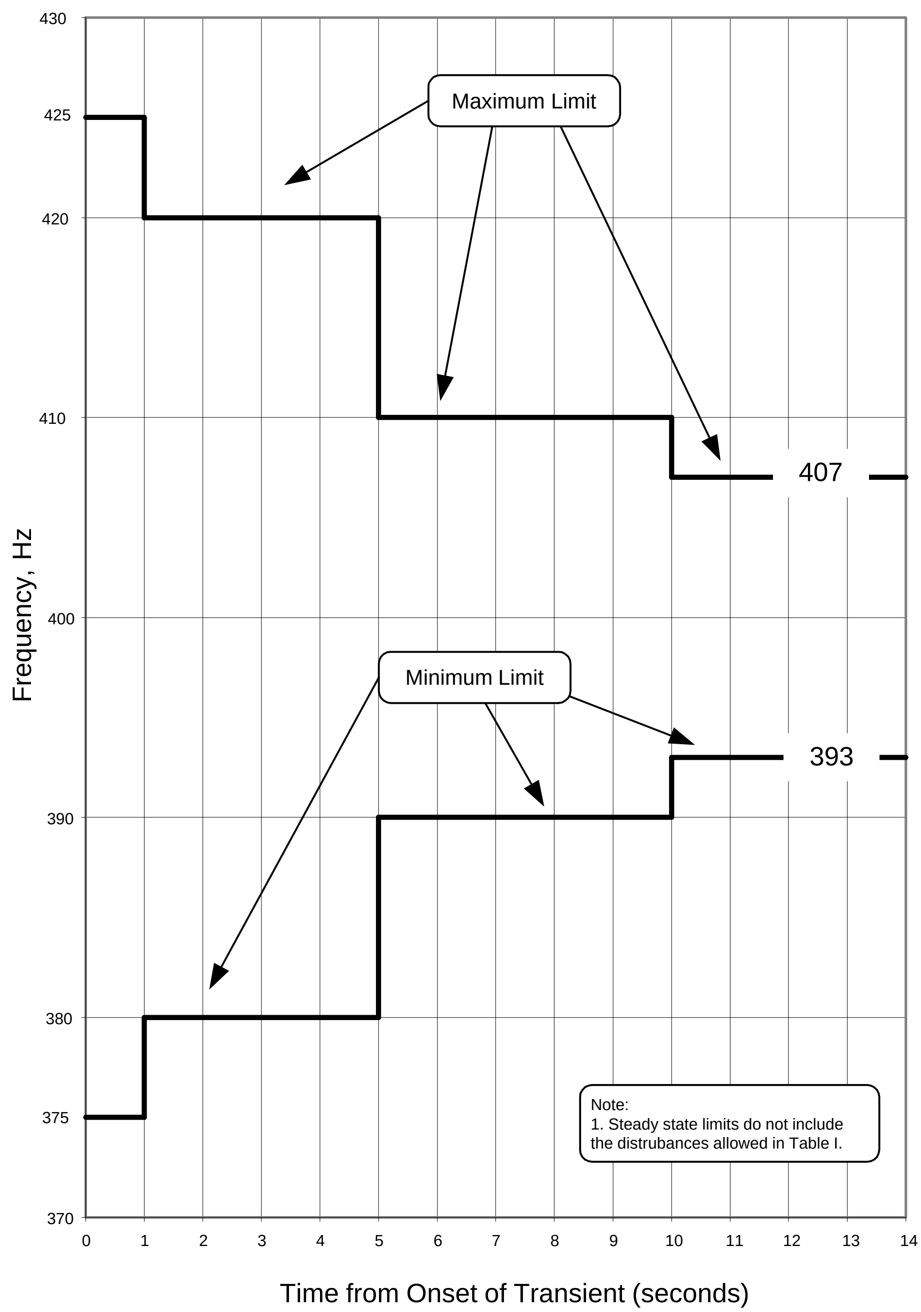


FIGURE 5. Envelope of normal 400 Hz AC frequency transient.

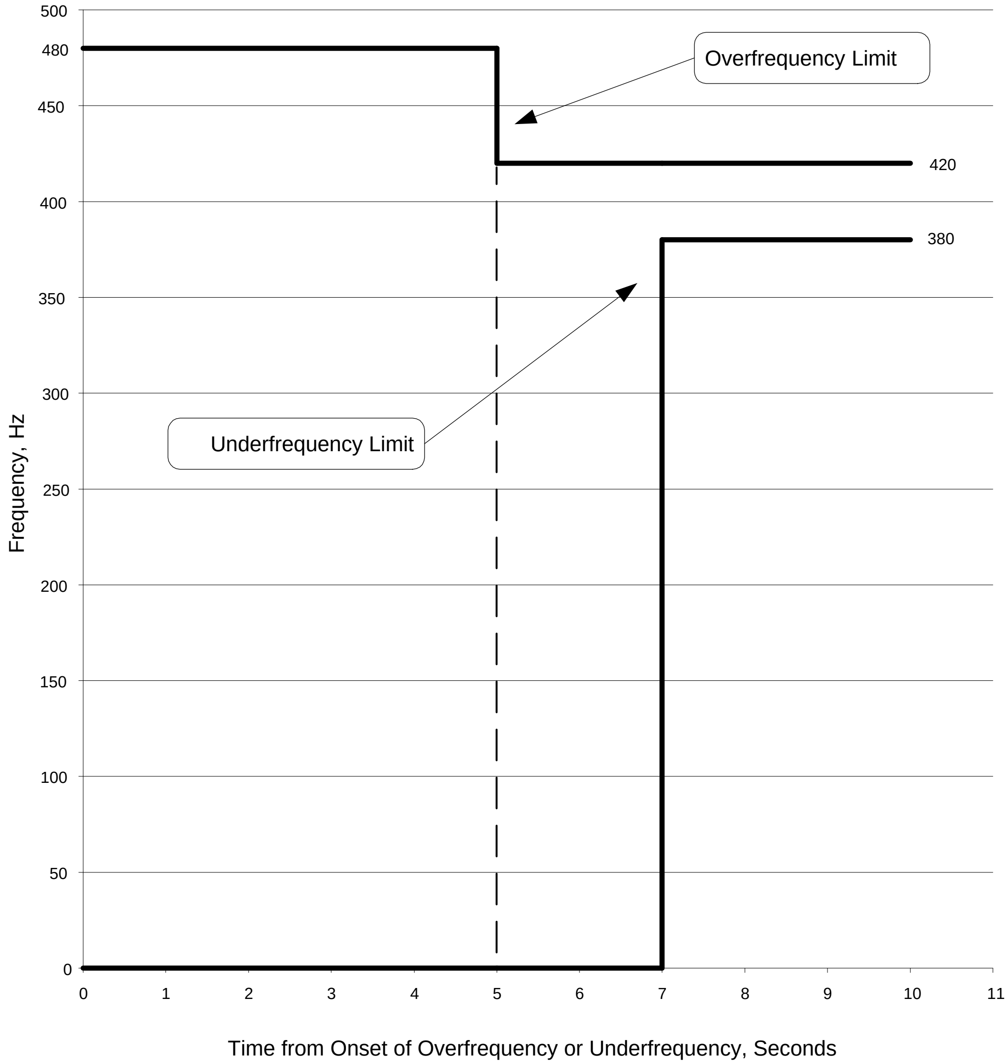
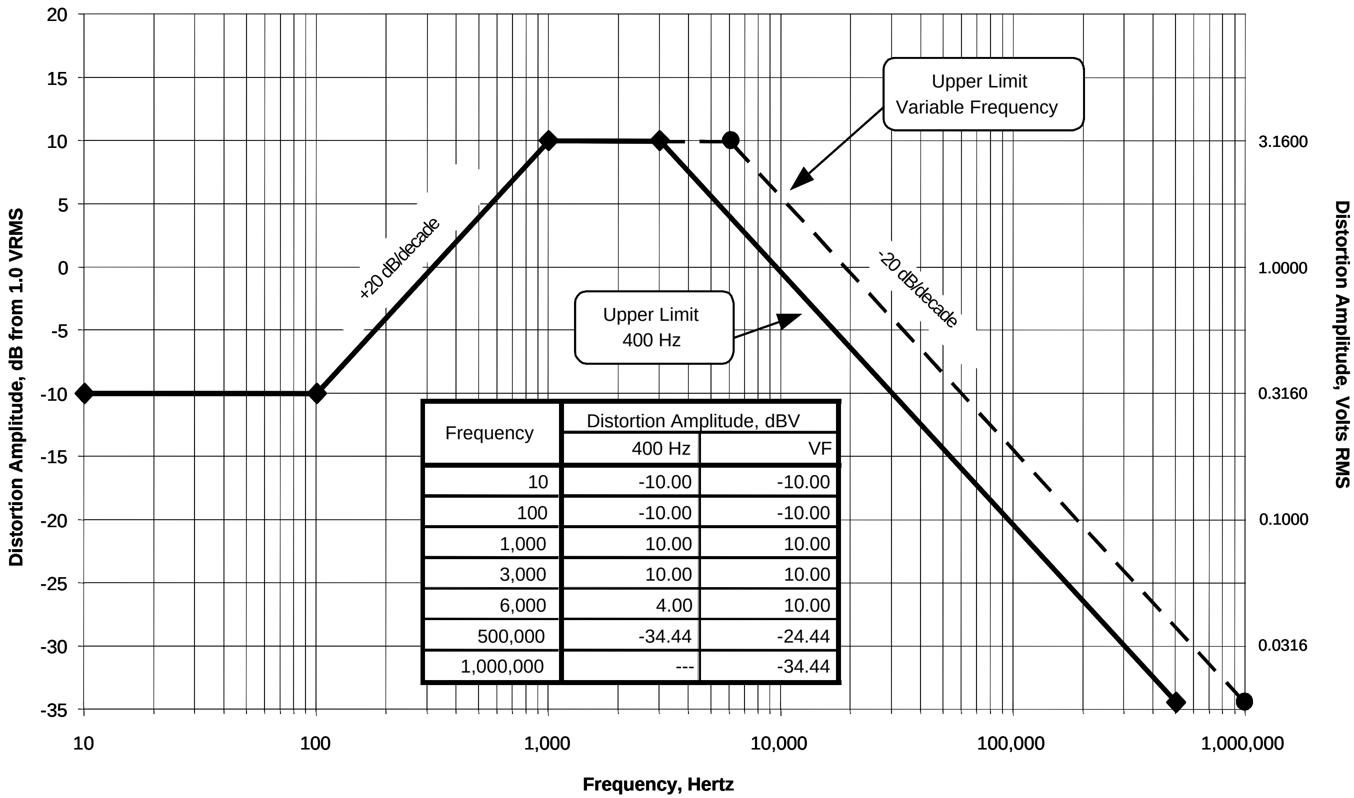


FIGURE 6. Limits for 400 Hz AC overfrequency or underfrequency.



Frequency	Distortion Amplitude, dBV	
	400 Hz	VF
10	-10.00	-10.00
100	-10.00	-10.00
1,000	10.00	10.00
3,000	10.00	10.00
6,000	4.00	10.00
500,000	-34.44	-24.44
1,000,000	---	-34.44

FIGURE 7. Maximum distortion spectrum of 400 Hz and variable frequency AC voltage.

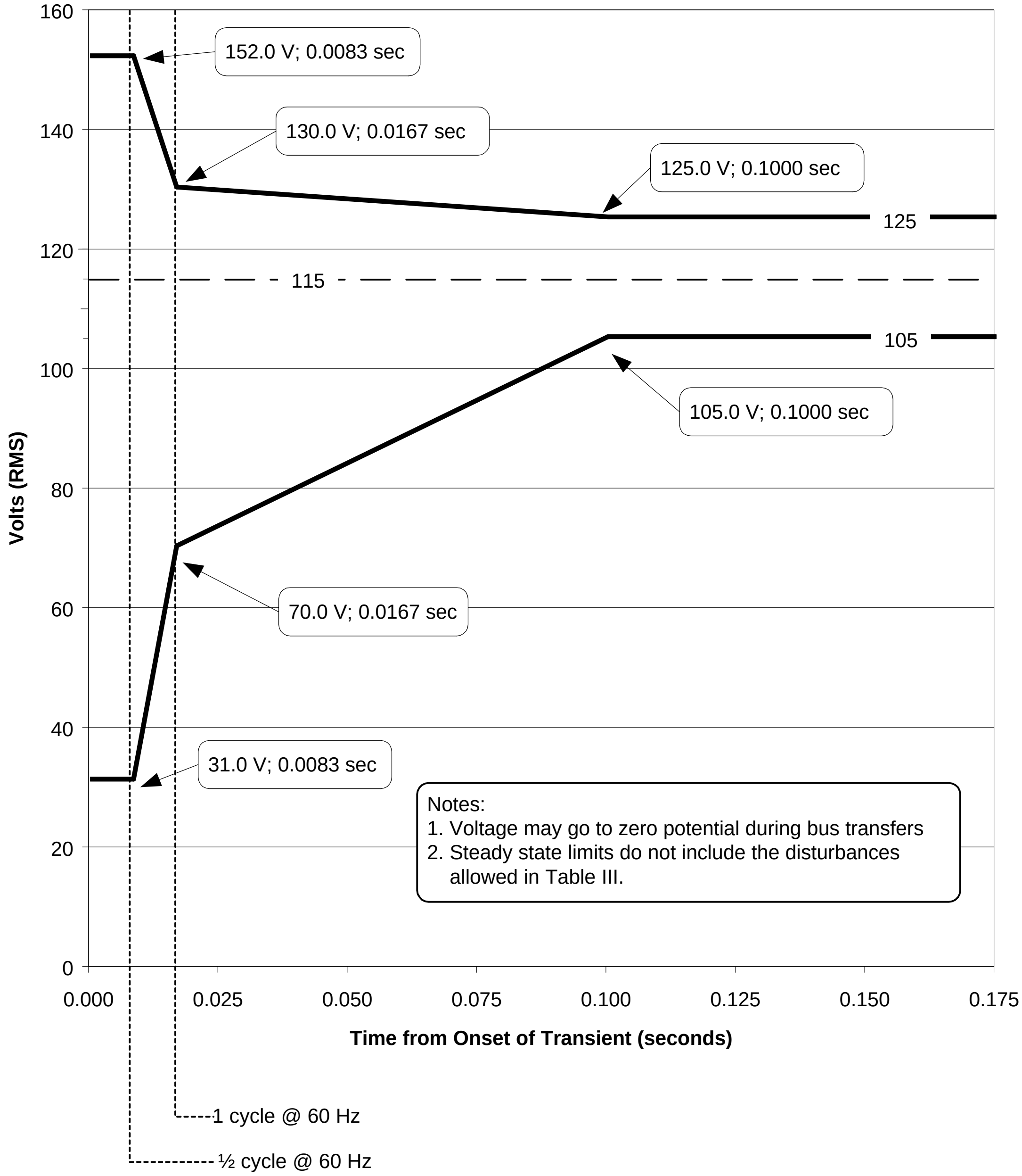


FIGURE 8. Envelope of normal 60 Hz voltage transient.

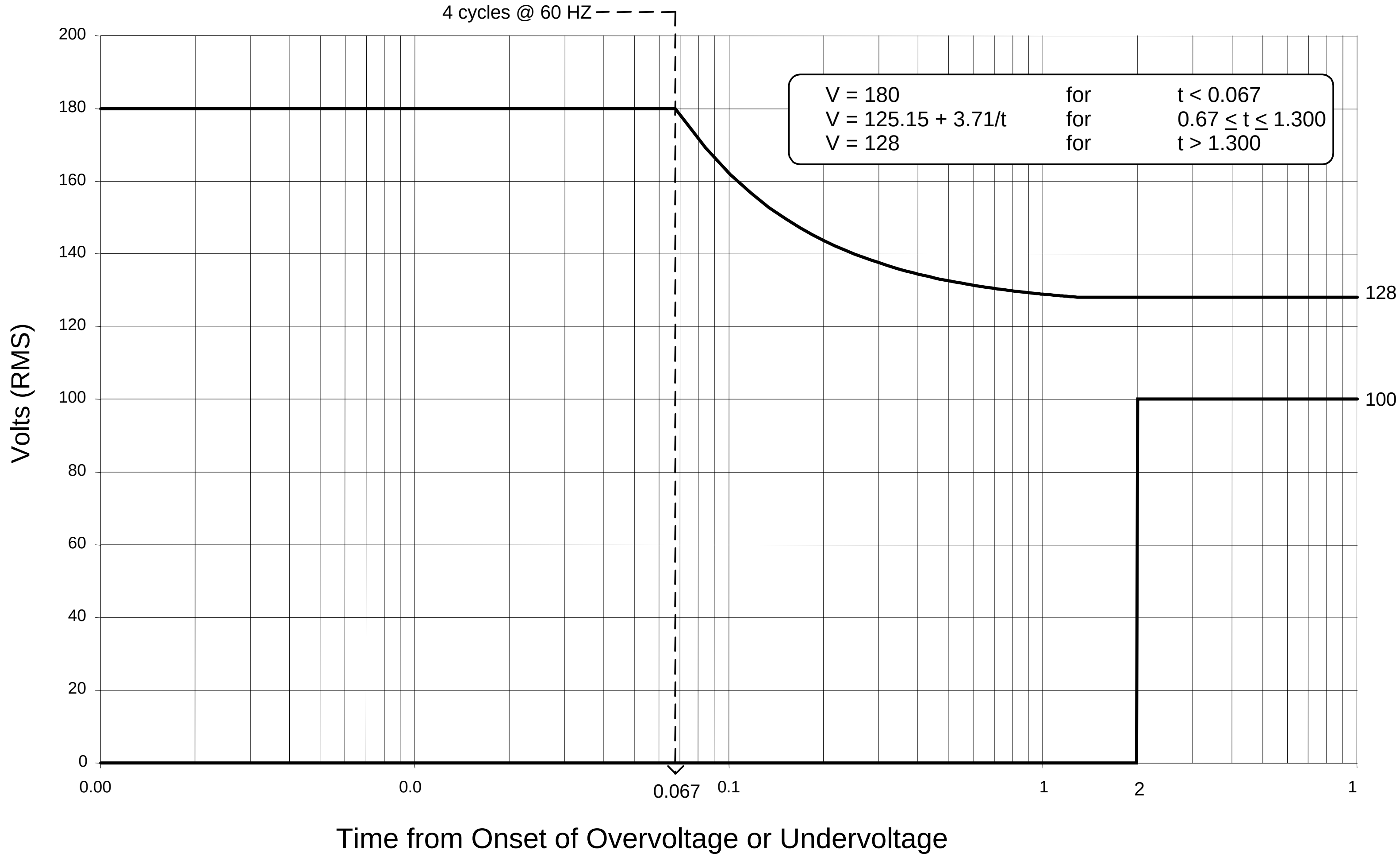


FIGURE 9. Limits for 60 Hz AC overvoltage and undervoltage.

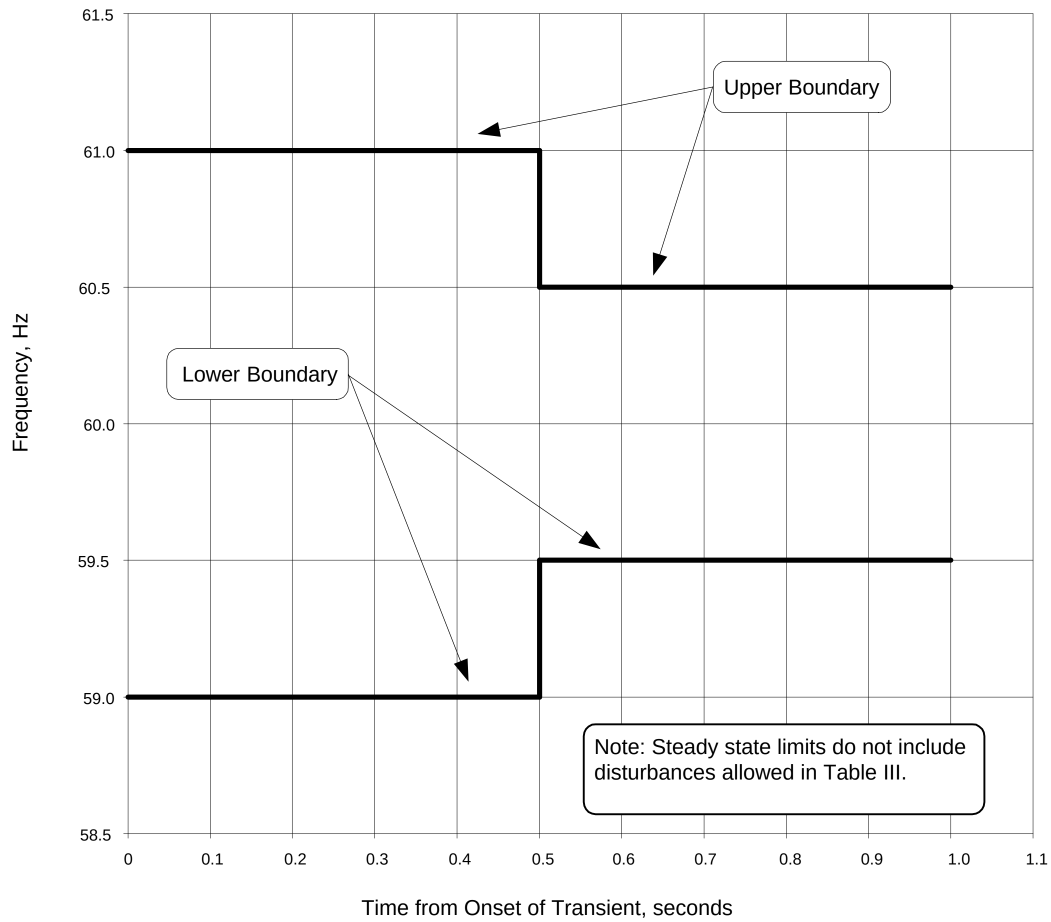


FIGURE 10. Envelope of normal 60 Hz AC frequency transient.

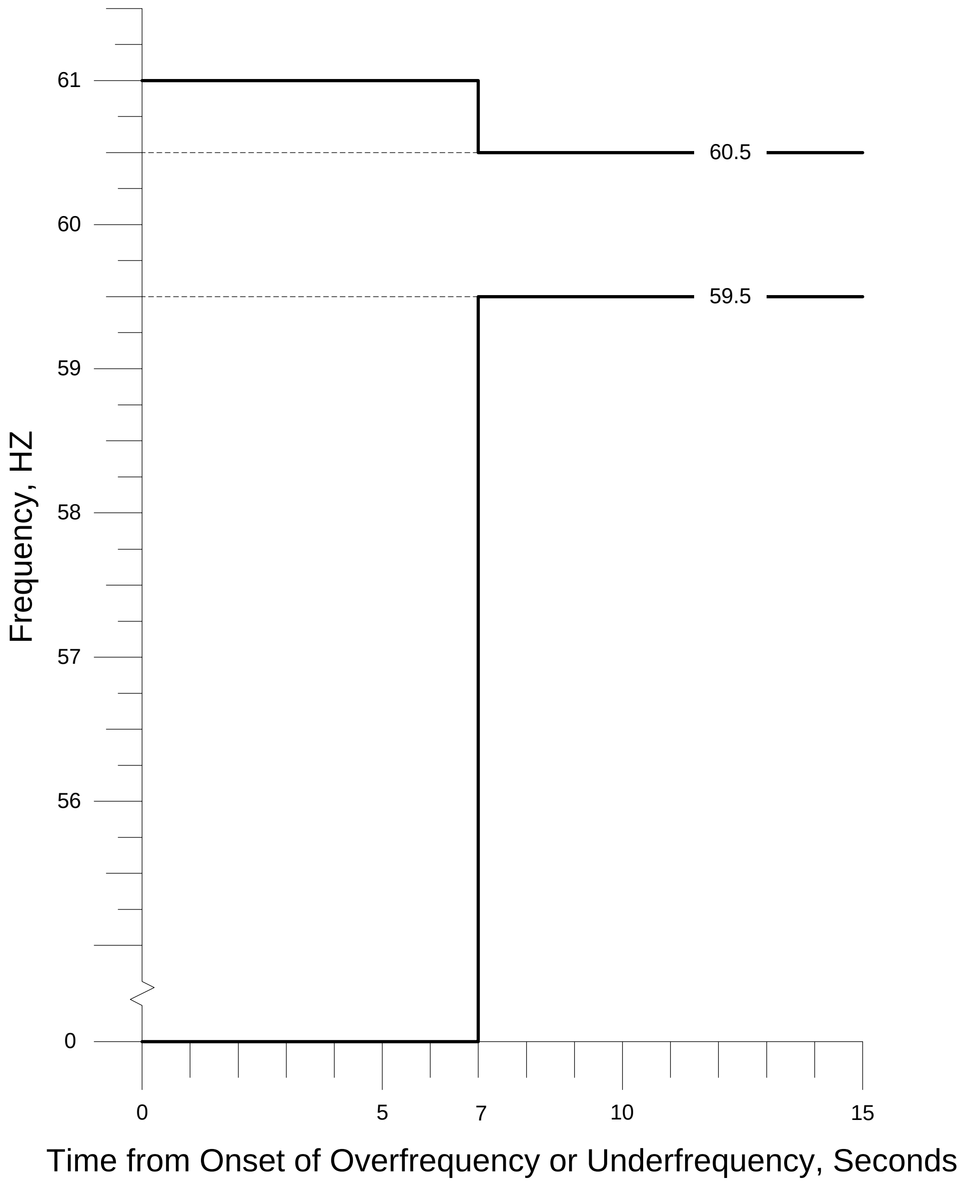


FIGURE 11. Limits for 60 Hz AC overfrequency and underfrequency.

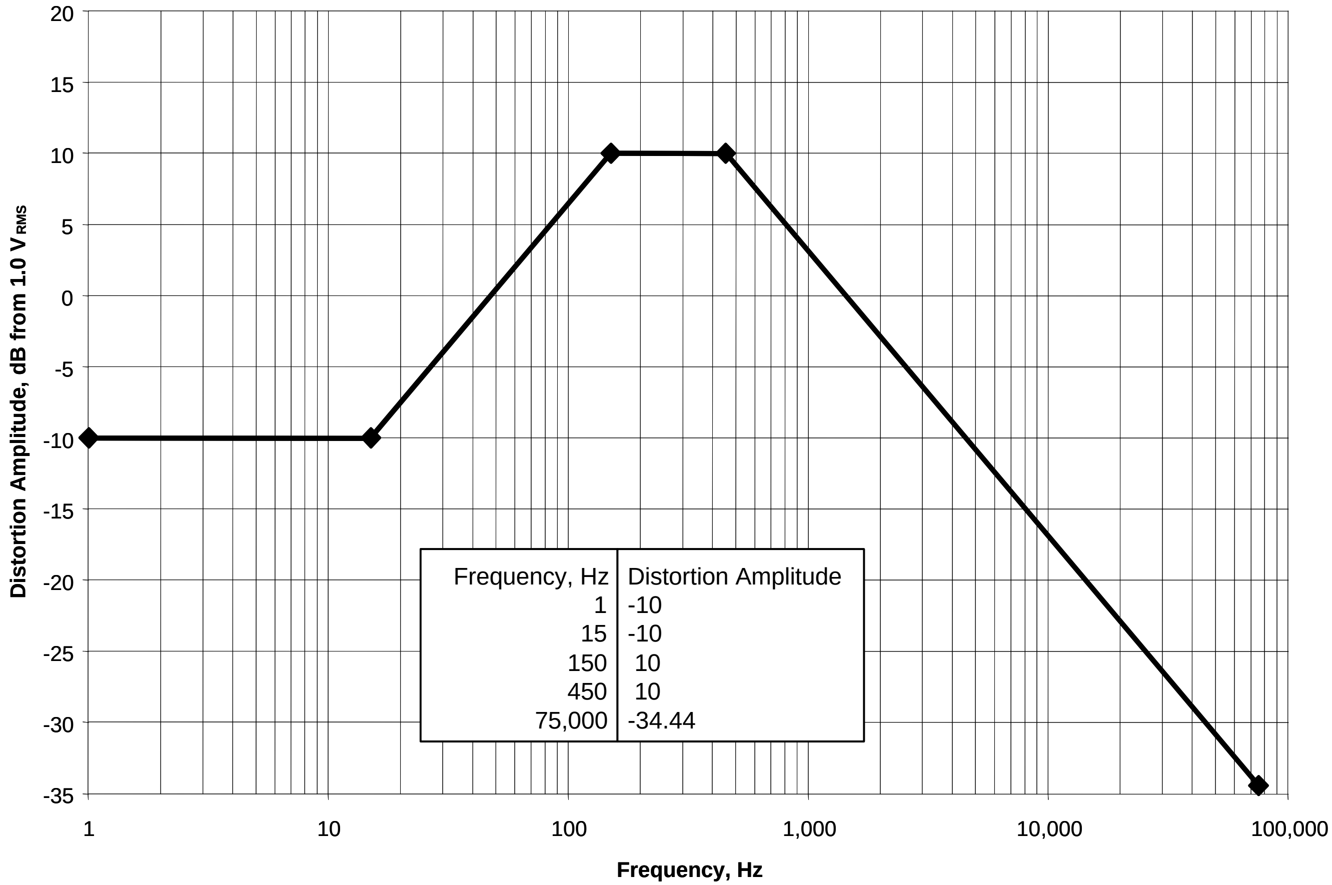


FIGURE 12. Maximum distortion spectrum of 60 Hz AC voltage.

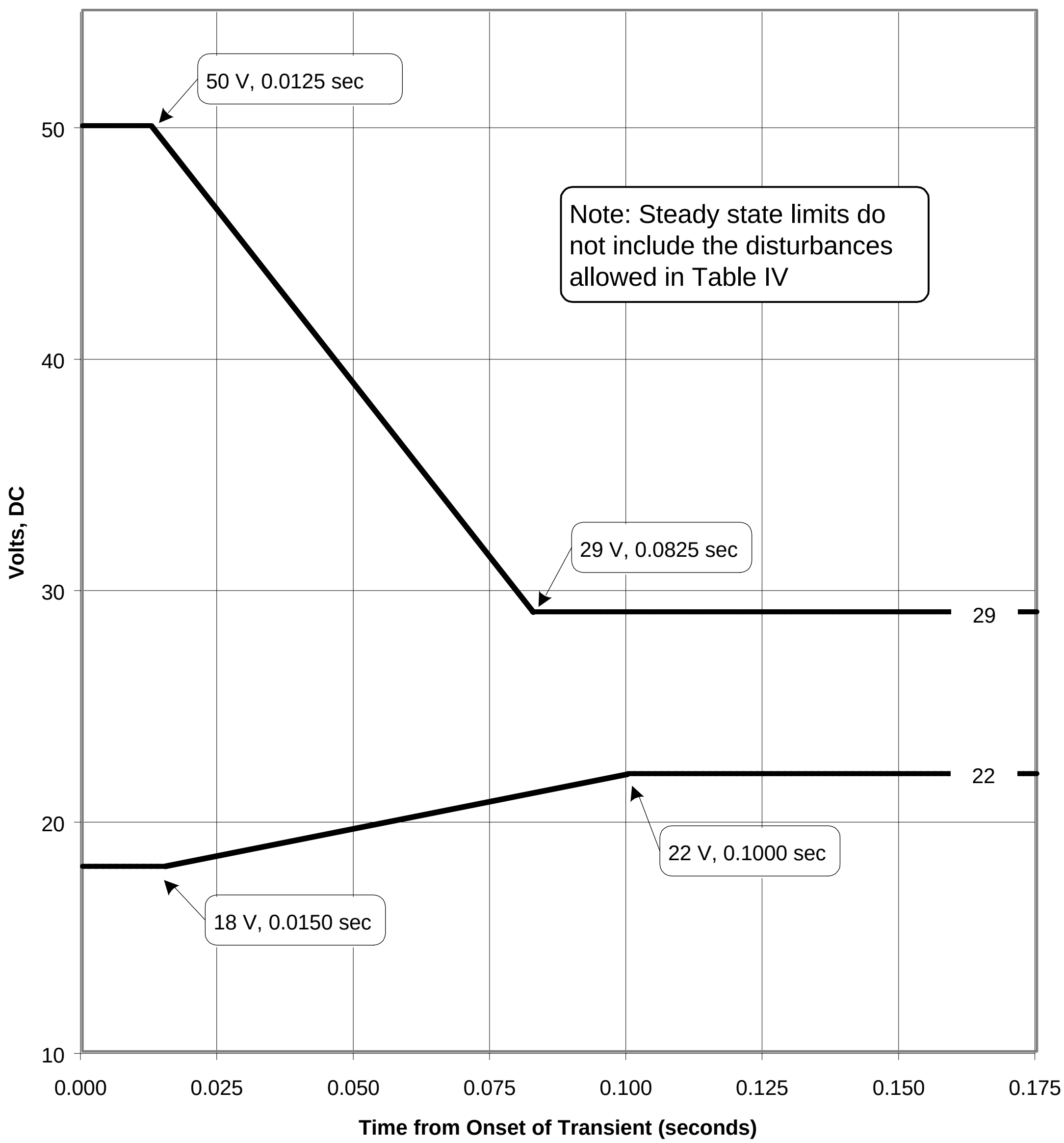


FIGURE 13. Envelope of normal voltage transients for 28 volts DC system.

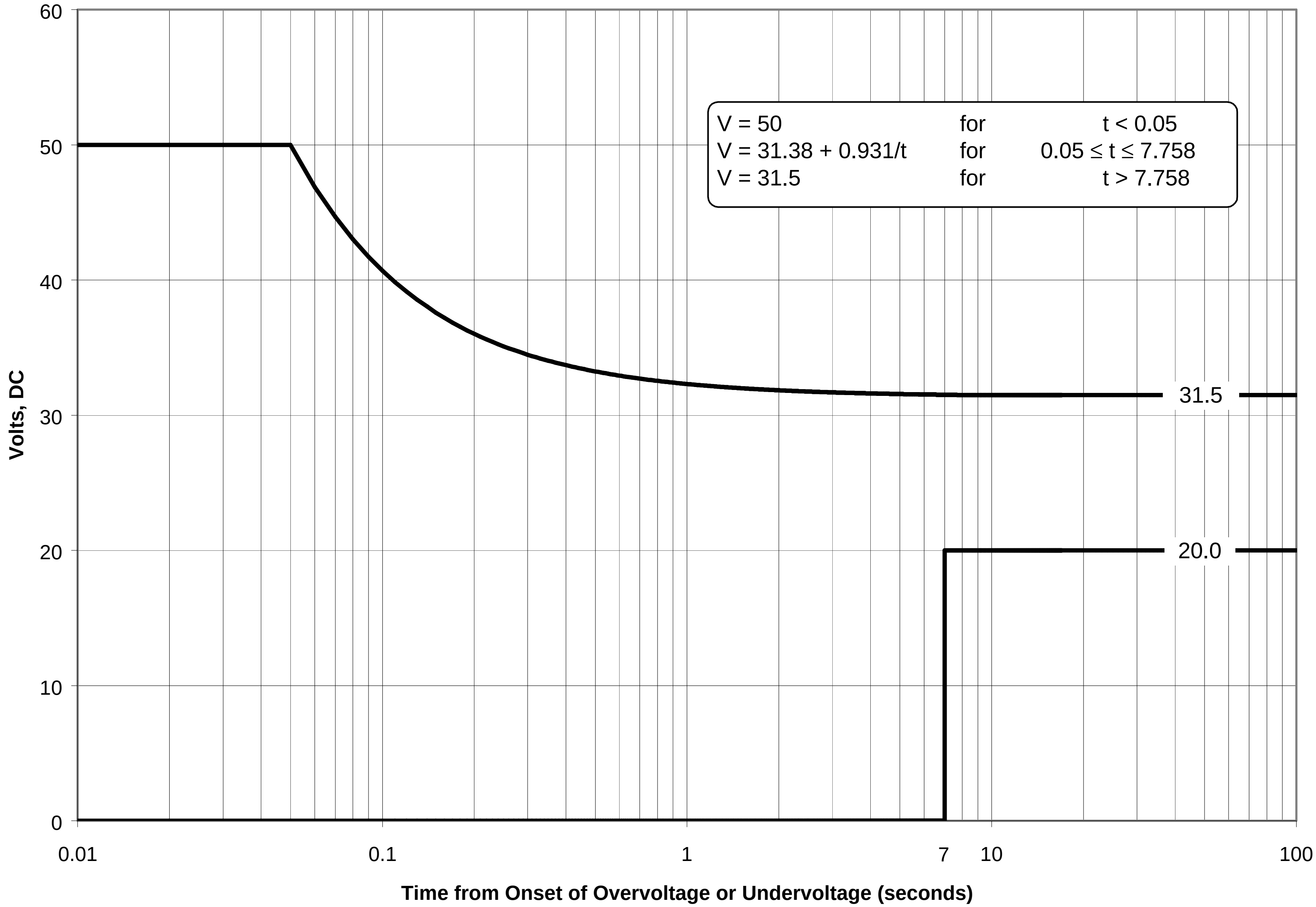


FIGURE 14. Limits for overvoltage and undervoltage for 28 volts DC system.

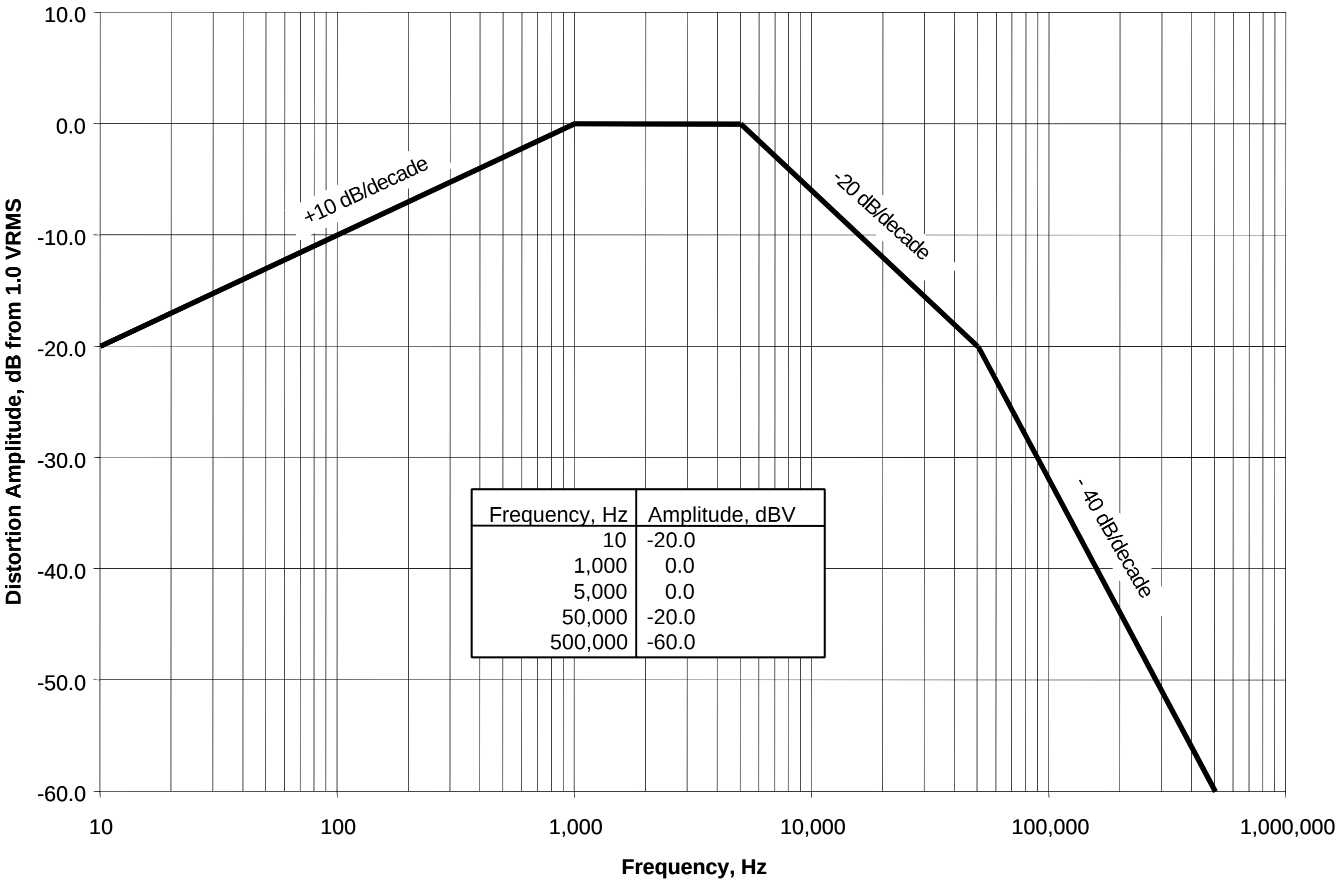


FIGURE 15. Maximum distortion spectrum for 28 volts DC system.

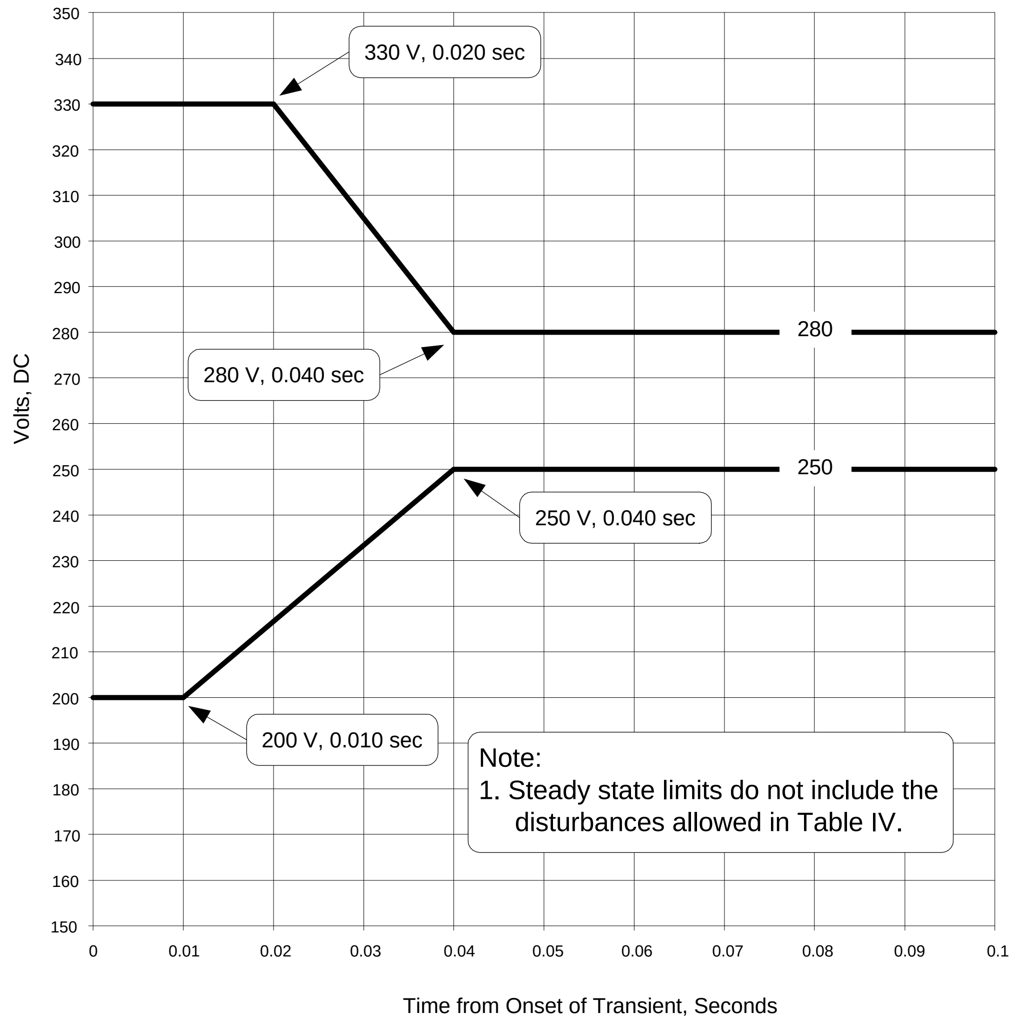


FIGURE 16. Envelope of normal voltage transient for 270 volts DC system.

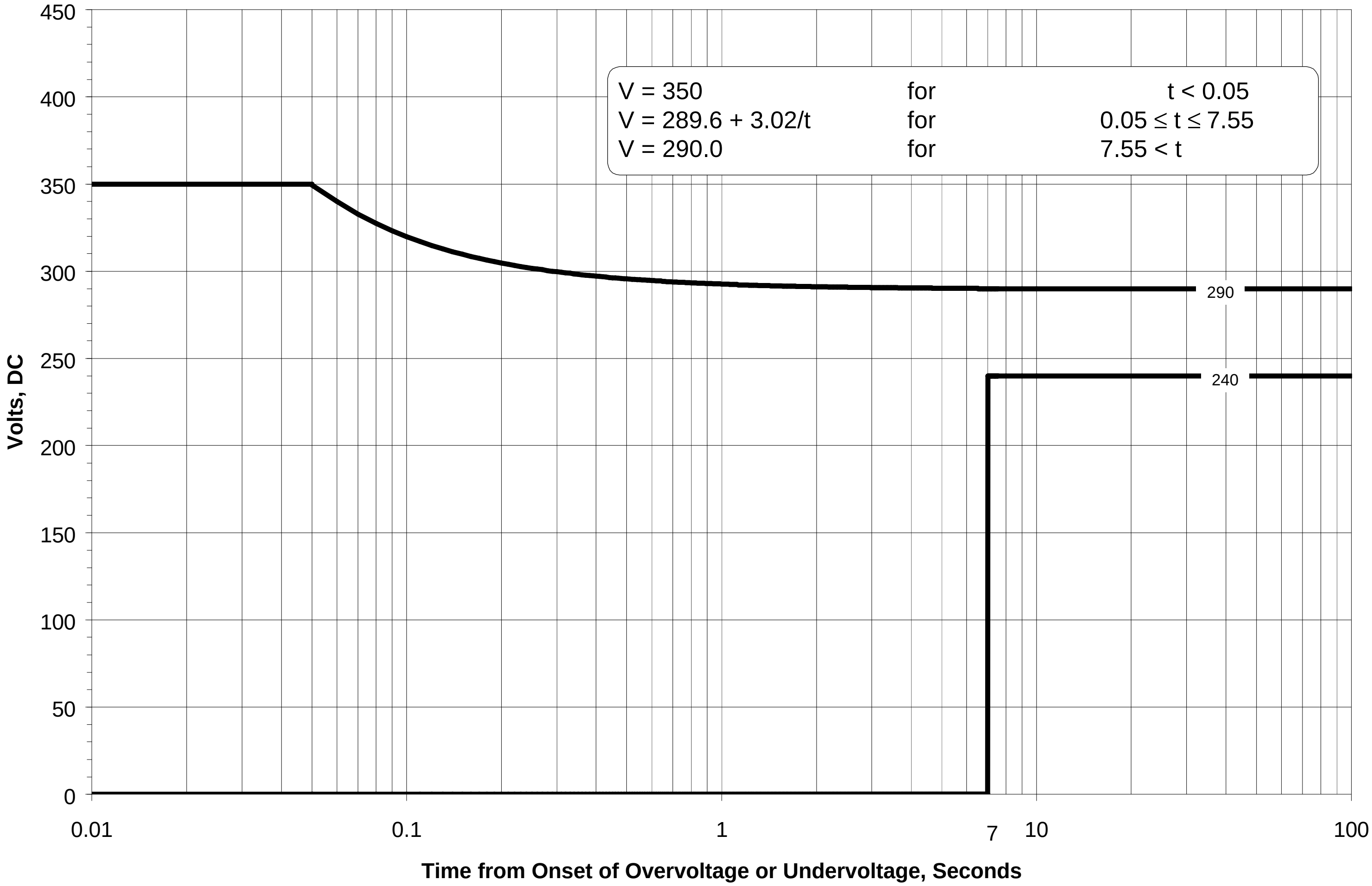
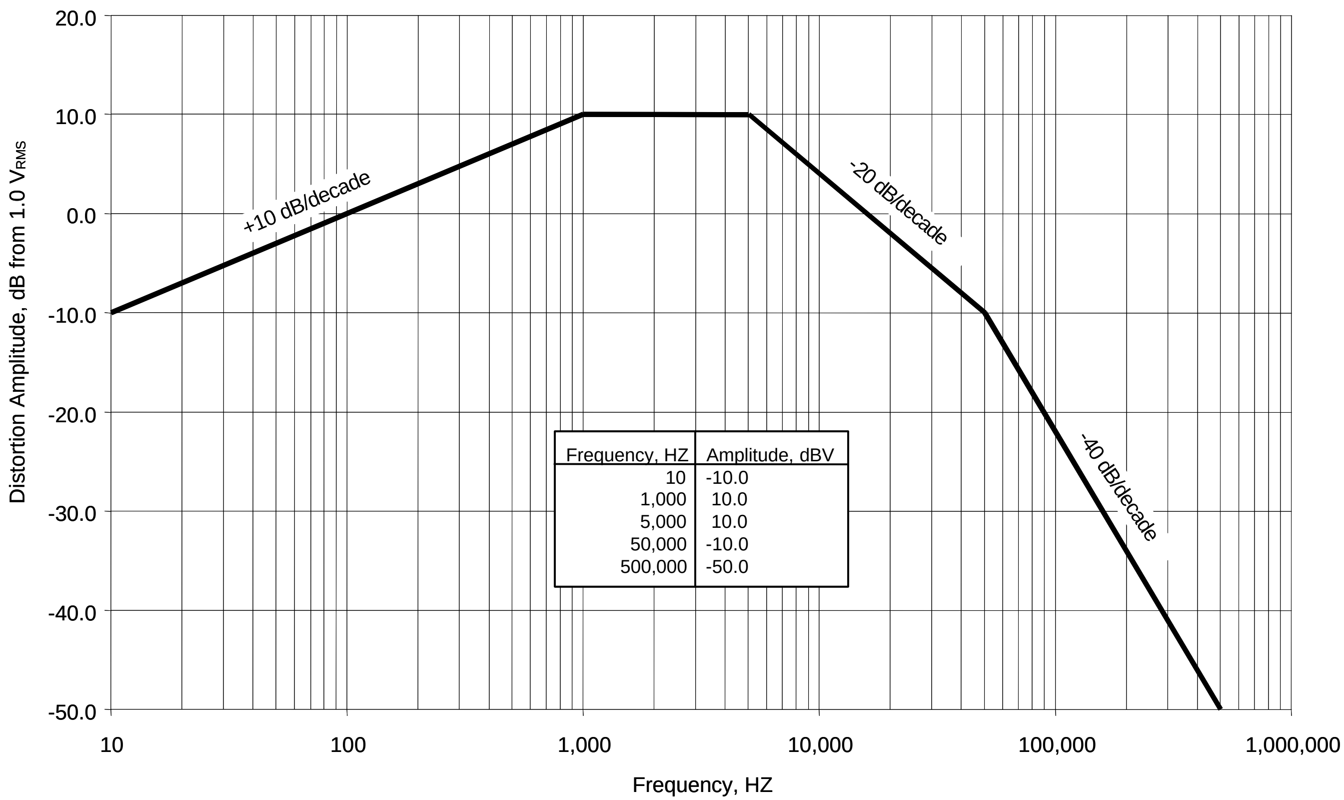


FIGURE 17. Limits for DC overvoltage and undervoltage for 270 volts DC system.



Frequency, HZ	Amplitude, dBV
10	-10.0
1,000	10.0
5,000	10.0
50,000	-10.0
500,000	-50.0

FIGURE 18. Maximum distortion spectrum for 270 volts DC system.

CONCLUDING MATERIAL

Custodians:
Army – AV
Navy – AS
Air Force - 11

Preparing Activity:
Navy - AS
(Project No. SESS – 0046)

Review Activities:
Army – CR, MI, TE
Navy - EC, MC, SH, YD

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://www.dodssp.daps.mil/.