PACIFIC POWER SOURCE

Selecting the Right Test Solution for Aerospace Compliance Standards

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Applications Engineering Manager at Pacific Power Source

Over 15 years of electrical engineering experience. Strong foundation in AC & DC systems with direct customer experience.

Leads and manages applications team. Influences product development, innovation, and continuous improvement. Previous senior roles at NI, NH Research, and Bureau Veritas.

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1. Industry Trends & Test Goals
2. Test Scenarios and Requirements of Electrical Components & Systems
3. Aerospace Compliance Landscape
4. Standards Overview: MIL-STD-704, DO-160
5. How to Select the Right Test Solution

Aerospace Industry Trends

- **Increased electrification** in commercial & military aviation.
- Objective to **reduce weight,** fuel **efficiency**, higher **performance**, **resilient power** distribution
- Shift from constant-frequency AC to **variable-frequency and high voltage DC systems (HVDC)**.
- Complex **transients & load** dynamics
- **Precise simulation** needed to meet compliance standards.

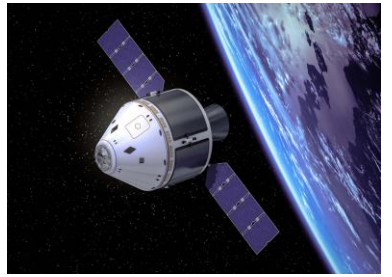
Commercial Airplanes

Military & Defense

eVTOL, Flying Taxis

Drones

Ground Support



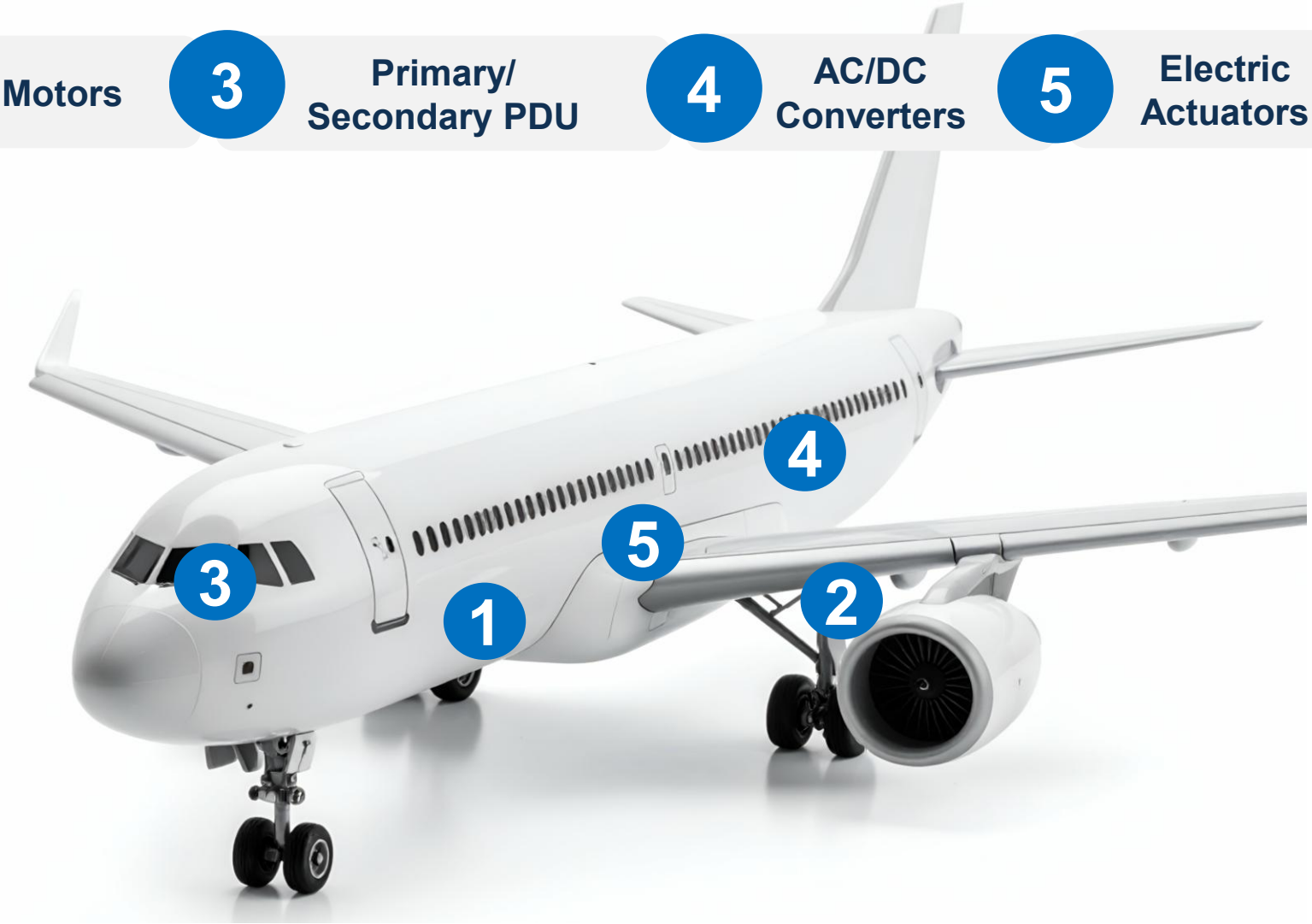
Space, Satellites

Power components of an aircraft

1. Battery
2. Motors
3. Primary/ Secondary PDU
4. AC/DC Converters
5. Electric Actuators

Subject to various electrical conditions in flight:

- inrush current
- voltage dropouts
- power line disturbances
- brownouts



Increasing Challenges

Traditional Systems

Constant Speed Drives (CSD)

Historically used for weight savings, smaller transformers

115V, 400 Hz AC

Modern Platforms

Efficient transitions, lighter cabling, frequency varies w/ engine speed.

Wild Frequency AC
360 to 800 Hz

High-voltage DC
270 VDC & 540 VDC

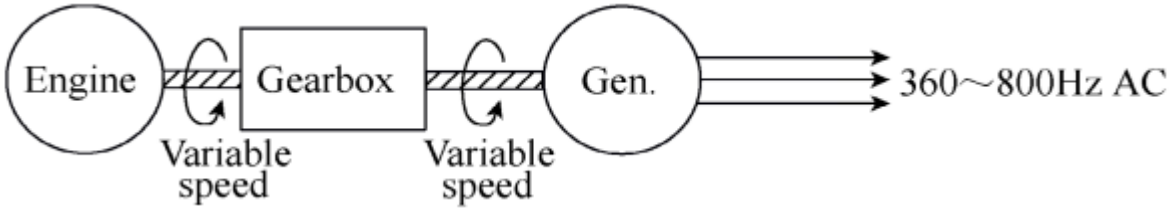
Shift Challenges:

- More complexity
- Higher frequency, currents & voltage
- More emphasis on interoperability

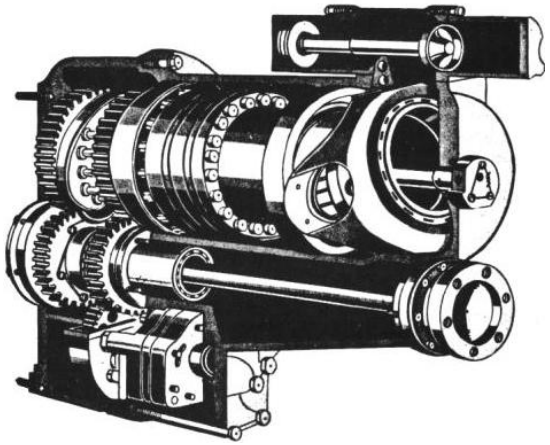
Impacts all avionics components (PDU, Motors, Power Converter, actuators, etc.)

What is Wild Frequency?

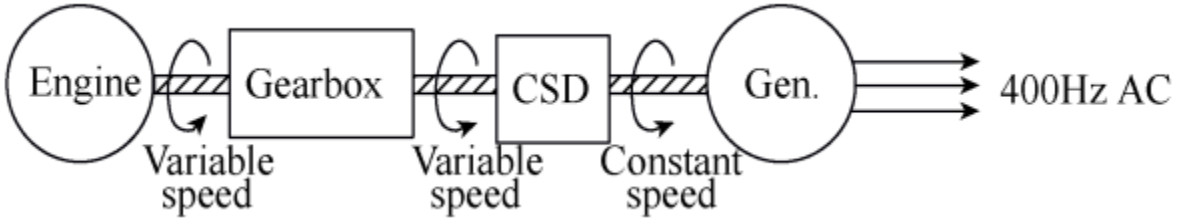
- **AC power with variable frequency**
  - Generated by aircraft engines or APU-driven generators



- **Characteristics**
  - Frequency varies with engine speed
  - Ranges between 360-800Hz



- **Eliminates Constant-Speed Drives (CSD)**
  - Reducing Weight, Complexity, System losses
  - Increases efficiency and flexibility in power generation



Test Goals in Aerospace Systems

Simulate real-world conditions accurately where we evaluate:

- Startup behavior
- Load regulation
- Transient response
- Immunity and fault scenarios

Ensure performance under:

- Various frequencies in AC
- Regenerative & inductive loads
- Harsh electrical environments

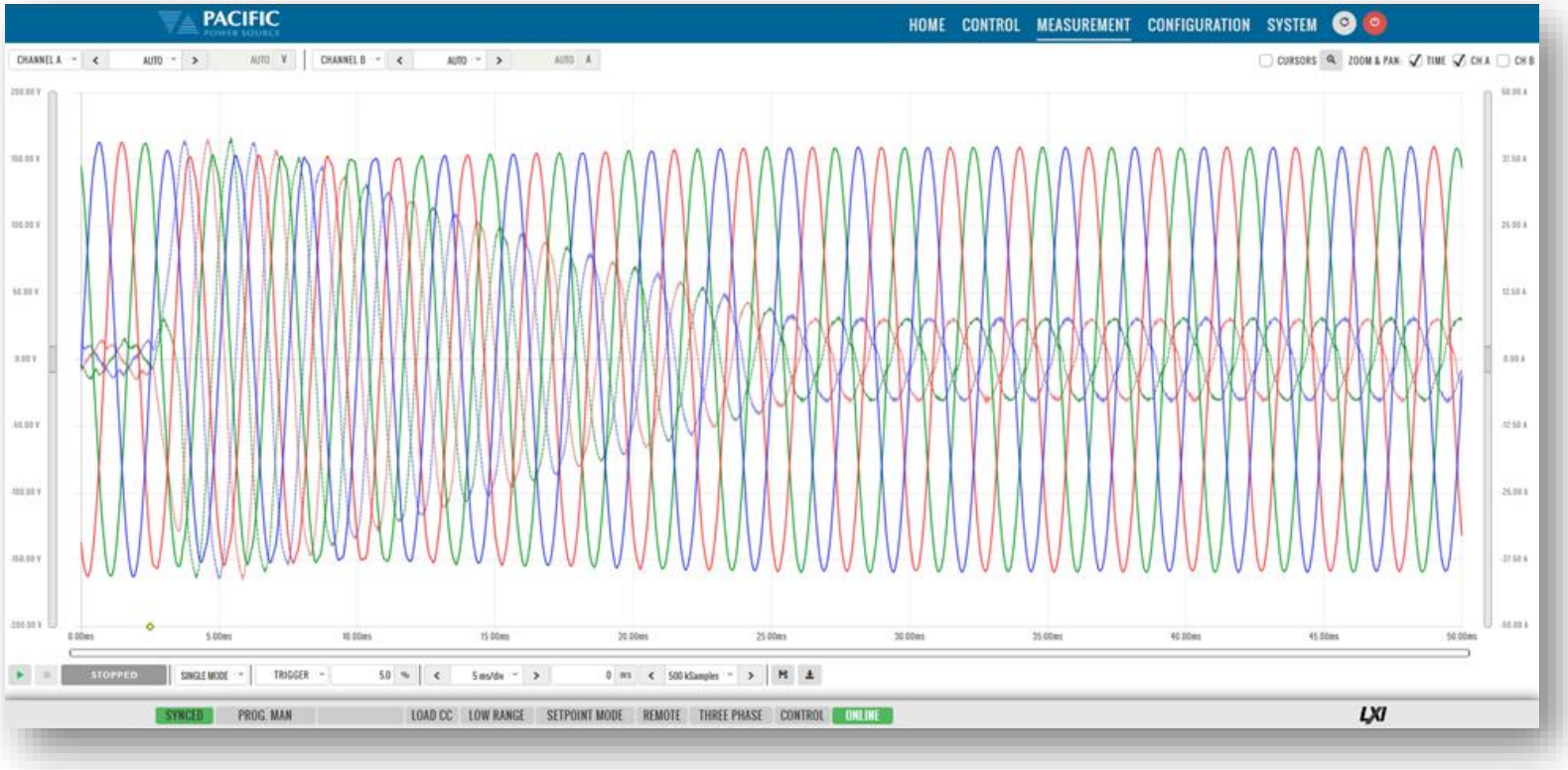
Engineering Characterization

- Start-up/shutdown sequencing
- Response to input transients, brownouts, surges
- Line/load regulation

Burn-In & Life Cycle

- Identify early-life failures
- Simulate years of operations
- Under full or near-full load (power)

Complex Load & Transient Requirements



AC motor: 3-phase inrush current start up

Application Examples:

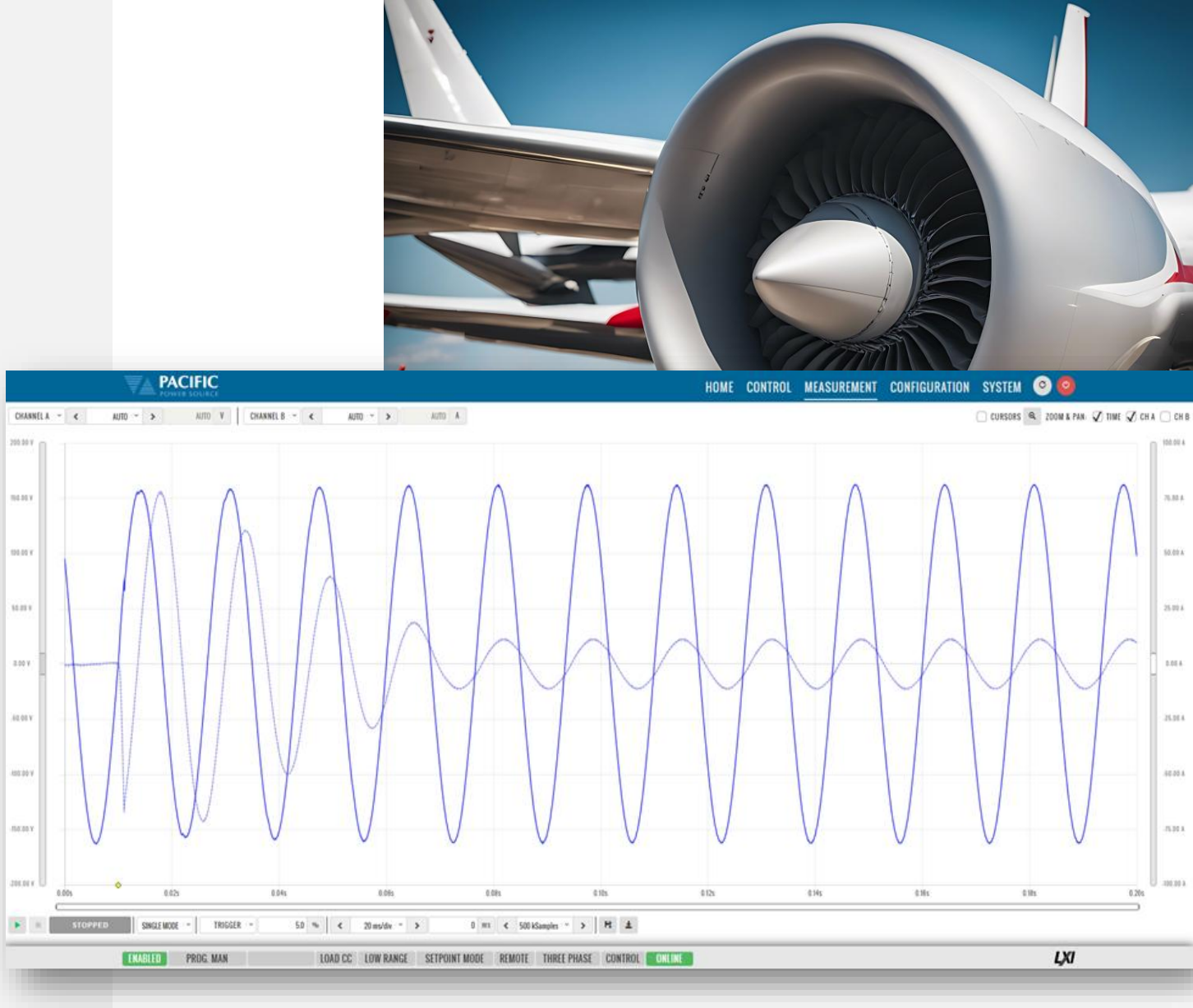
Aircraft Power Systems

- **AC motors:** Inrush current at start-up
- **Regenerative scenarios:** actuator flyback energy
- **Power line disturbances (PLD):** Undervoltage, overvoltage, frequency shifts, sags, surges
- **Power Converters:** Clean or distorted AC source and loads

Aerospace Manufacturer

Induction Motors / Inductive Loads

- 120/208 VAC 60Hz Source
- Powering an AC motor
- Inrush during power on, low power factors
- Closer to unity at steady state



Sourcing an AC motor (inductive)

Aerospace Supplier

Test converters/actuators that power the rails to move cargo loads onto planes

- 115V/400Hz Source
- Powering various components
- Hours/weeks/months of testing
- Burn-in/Life Cycle

Source: https://ancraaircraft.com/cargo-loading-systems/

The Aerospace Compliance Landscape

Conforms to **regulatory**, **industry**, or **manufacturer-specific standards**

Standards define conditions for voltage, frequency, and transients.

Standard	Applies To	Key Focus Areas
RTCA/DO-160 Sec 16	Commercial aircraft	Power input behavior. Equipment operation when subject to various cond.
MIL-STD-704 A/F	Military aircraft	Power characteristics of aircraft electrical systems.
MIL-STD-1399-300	Military ships	Power characteristics of shipboard electrical systems
Airbus ABD0100.1.8/1.8.1	A380 / A350	AC/DC voltage transients, freq. variations
Boeing 787B3-0147	787 Dreamliner	Variable Frequency and HVDC (270VDC), AC/DC voltage transients, freq. variants

Electrical Tests

- Steady-state operation at nominal & abnormal voltages/frequencies
- Voltage spikes, transients, power interruptions
- DC ripple & inrush current
- Frequency variation

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MIL-704A-F & RTCA DO-160

Standards Overview

What is MIL-STD-704A-F?

- Ensures **all avionics & electrical systems on military aircraft operate reliably** in airborne environments without damaging connected equipment (compatible).
- The standard defines **voltage ranges, frequency variations, transients, interruptions**, and **distortions**, and gives **guidance on testing conditions.**
- Critical part of **aerospace qualification** & **system-level integration** in military platforms

MIL STD 704 Power Groups

- Used to categorize different electrical power systems
- Classify aircraft power sources and types of power DUT is designed to accept

The following power groups are included in the MIL-STD-704F test option. MIL-STD-704A covers fixed frequency only.

Power Group	Description	Nominal Voltage	Nominal Frequency	Phase Modes
SAC	Single-Phase, 400 Hz Constant Frequency, 115 V	115Vrms L-N	400Hz	Single Phase
TAC	Three-Phase, 400 Hz Constant Frequency, 115 V	115Vrms L-N	400Hz	Three Phase
SVF	Single-Phase, Variable Frequency, 115 V	115Vrms L-N	360 – 800Hz	Single Phase
TVF	Three-Phase, Variable Constant Frequency, 115 V	115Vrms L-N	360 – 800Hz	Three Phase
SXF	Single-Phase, 60 Hz Constant Frequency, 115 V	115Vrms L-N	60Hz	Single Phase
LDC[1]	28VDC utilization equipment MIL-STD-704 compliance tests	28Vdc	n/a	n/a
HDC[1]	270VDC utilization equipment MIL-STD-704 compliance tests	270Vdc	n/a	n/a

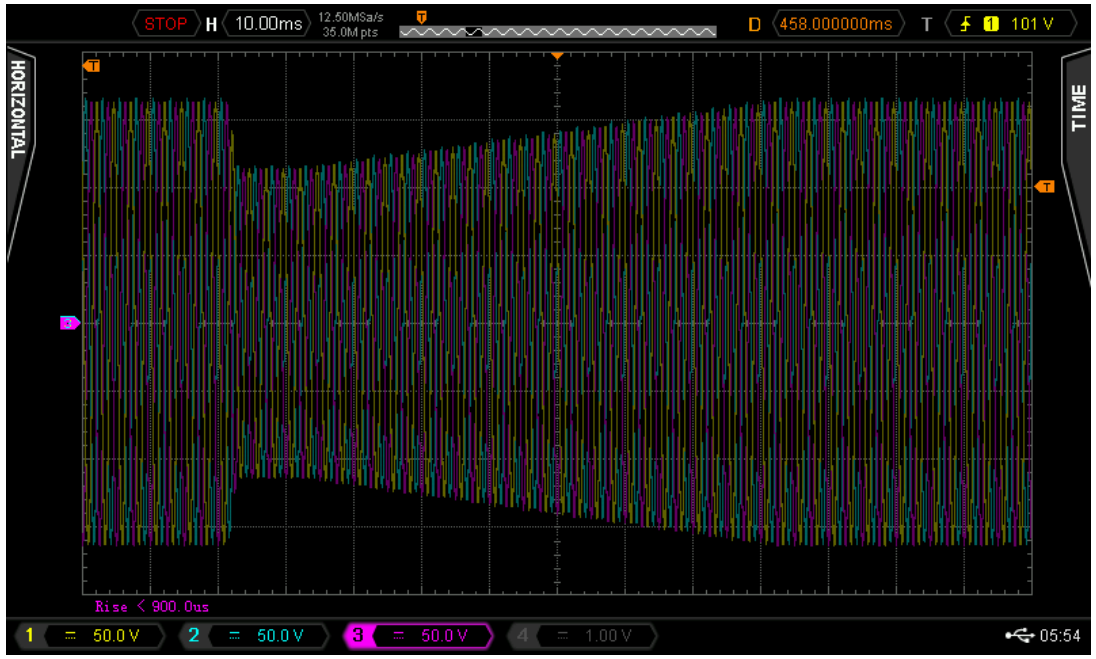
MIL STD 704 Test Description and Applicability - AC

Compliance Matrix MIL-STD-704F

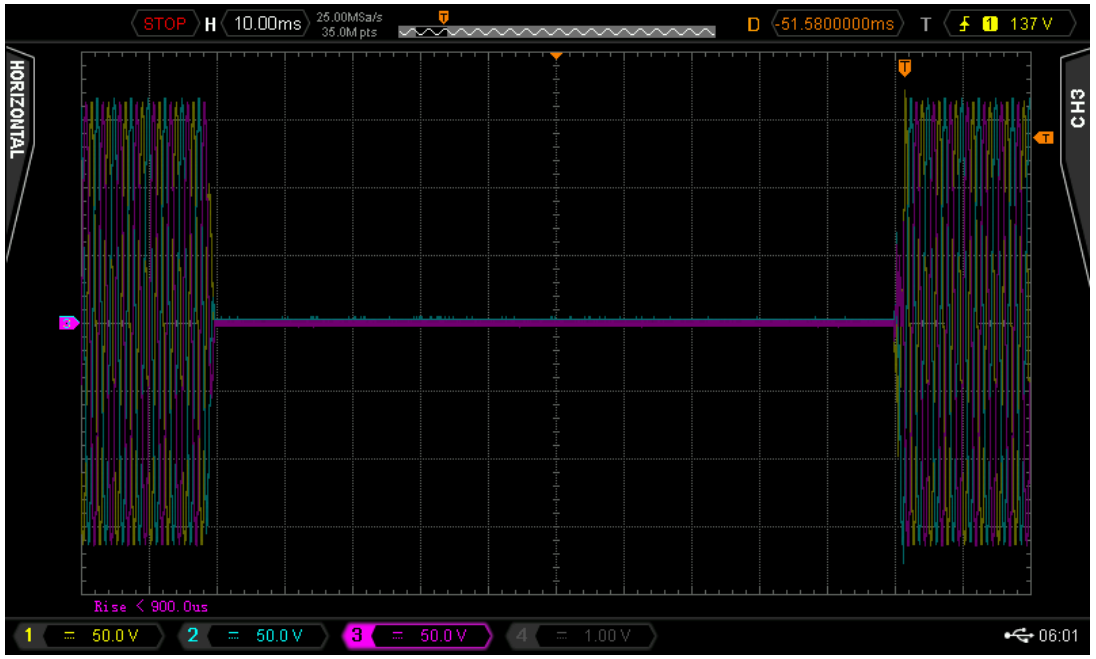
Test	Description	SAC	TAC	SVF	TVF	SXF	Notes
Normal Operation (1xx)							
101	Load and Current Harmonics Measurements	Y	Y	Y	Y	Y	Additional Power Measurement Equipment recommended for capturing for UUT performance
102	Steady State Limits	Y	Y	Y	Y	Y	
103	Voltage Phase Difference	N/A	Y	N/A	Y	N/A	Not applicable for Single phase UUT's
104	Voltage Modulation	Y	Y	Y	Y	Y	
105	Frequency Modulation	Y	Y	Y	Y	Y	
106	Voltage Distortion Spectrum	M/R	M/R	M/R	M/R	M/R	Requires Function Generator, Spectrum Analyzer, 50uH inductors, 10uF Cap
107	Total Voltage Distortion	Y	Y	Y	Y	Y	
108	DC Voltage Component	Y	Y	Y	Y	Y	Requires AFX in AC+DC Mode
109	Normal Voltage Transients	Y	Y	Y	Y	Y	Requires Split Phase mode (FORM2) or Transformer (XFMR) for Single Phase, and Transformer(XFMR) for Three Phase UUT's
110	Normal Frequency Transients	Y	Y	Y	Y	Y	
Transfer (2xx)							
201	Power Interrupt	Y	Y	Y	Y	Y	Requires Split Phase mode (FORM2) or Transformer (XFMR) for Single Phase, and Transformer(XFMR) for Three Phase UUT's
Abnormal Operation (3xx)							
301	Abnormal Limits for Voltage and Frequency	Y	Y	Y	Y	Y	
302	Abnormal Voltage Transients	Y	Y	Y	Y	Y	Requires Split Phase mode (FORM2) or Transformer (XFMR) for Single Phase, and Transformer(XFMR) for Three Phase UUT's
303	Abnormal Frequency Transients	Y	Y	Y	Y	Y	
Emergency Operation (4xx)							
401	Emergency Limits for Voltage and Frequency	Y	Y	Y	Y	Y	
Starting (5xx)							
501	Not Typically Required	N/A	N/A	N/A	N/A	N/A	Not applicable to AC powered equipment
Power Failure (6xx)							
601	Power Failure	Y	Y	Y	Y	Y	
602	One Phase and Two Phase Power Failures	N/A	Y	N/A	Y	N/A	
603	Phase Reversal	Y	Y	Y	Y	Y	

Examples of AC Waveforms

MIL STD 704



Voltage Transients
TAC Section 109 ('Normal Voltage Transient')



Momentary Power Interruption
TAC Section 201 ('Power Interrupt')

MIL STD 704 Test Description and Applicability – DC

MIL STD 704F

DC Test[1]	Description	LDC	HDC	Notes
Normal Operation (1xx)				
101	Load Test	Y	Y	Ext. Meas. Equipment
102	Steady State Limits for voltage	Y	Y	
103	Voltage Distortion Spectrum	R	R	Additional Equip. Req.
104	Total Ripple	M / R	M / R	AFX or ext. equipment
105	Normal Voltage Transients	Y	Y	
Transfer Operation (2xx)				
201	Power Interrupt	Y	Y	
Note1 : All DC tests require AFX Series				

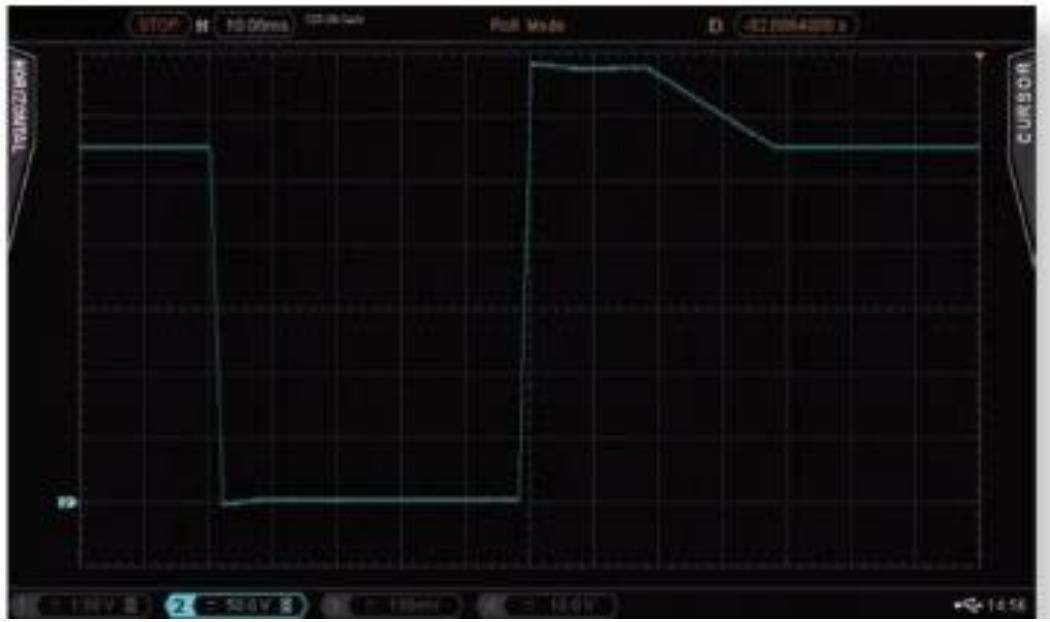
DC Test[1]	Description	LDC	HDC	Notes
Abnormal Operation (3xx)				
301	Abnormal Steady State Voltage	Y	Y	
302	Abnormal Voltage Transients	Y	Y	
Emergency Operation (4xx)				
401	Transparency Time	Y	Y	
Starting Operation (5xx)				
501		Y	Y	
Power Failure Operation (5xx)				
601	Power Failure	Y	Y	
602	Polarity Reversal	Y	Y	Requires AFX in DC Mode

Notes: Y = Full support. No additional equipment is needed to perform the required AC stimulus
R = Requires additional equipment. Refer to actual Test Standard Documents for details.
N = Not supported
N/A = Not Applicable - No Test required
M = Additional Measurement Equipment required
Z = Prog-Z required

Examples of DC Waveforms

MIL STD 704

LDC 105 Sequence (Momentary Over-Voltage) @50S/div Multiple Test Conditions



HDC 201 Cond K (Max steady-state overvoltage) @10mS/div Sequence

RTCA DO-160: Commercial Airborne Equipment

Ensures equipment reliability in real-world settings.

- Section 16: Power Input
- Section 17: Voltage Spike
- Section 18: Conducted Susceptibility

Test scenarios:

Voltage over/under-variation, power interrupts, spike/surges, and frequency anomalies.

For example, simulating a 250 ms voltage dropout requires precise timing and slope control.

Your power system must deliver these profiles accurately.

Failures in these tests can delay certification or even ground a platform.

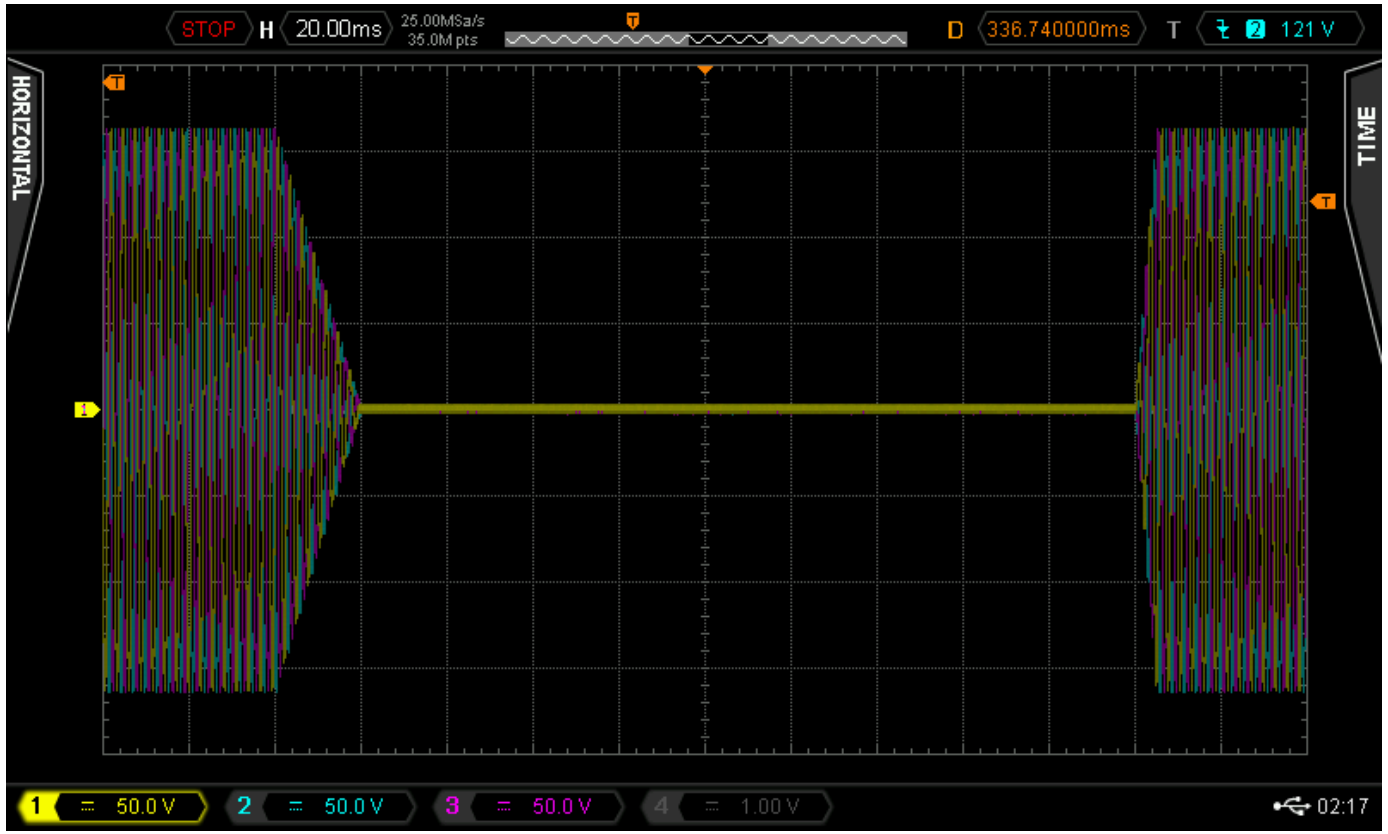
DO-160 Power Groups

RTCA DO-160

Power Group	Description	Nominal Voltage	Nominal Frequency	Phase Modes
ACF	AC Power, Constant Frequency	115Vrms L-N	400Hz	1 Phase and 3 Phase
		230Vrms L-N		
ANF	AC Power, Narrow Variable Frequency	115Vrms L-N	360 – 800Hz	
		230Vrms L-N		
AWF	AC Power , Wide Variable Frequency	115Vrms L-N	360 – 800Hz	
		230Vrms L-N		
Cat.A, 28dc	DC Power Test	28 Vdc	n/a	n/a
Cat B, 14Vdc	DC Power Test	14 Vdc	n/a	n/a
Cat B, 28Vdc	DC Power Test	28 Vdc	n/a	n/a
Cat Z, 28Vdc	DC Power Test	28 Vdc	n/a	n/a
Cat D, 270Vdc	DC Power Test	270 Vdc	n/a	n/a

Example of AC Waveforms

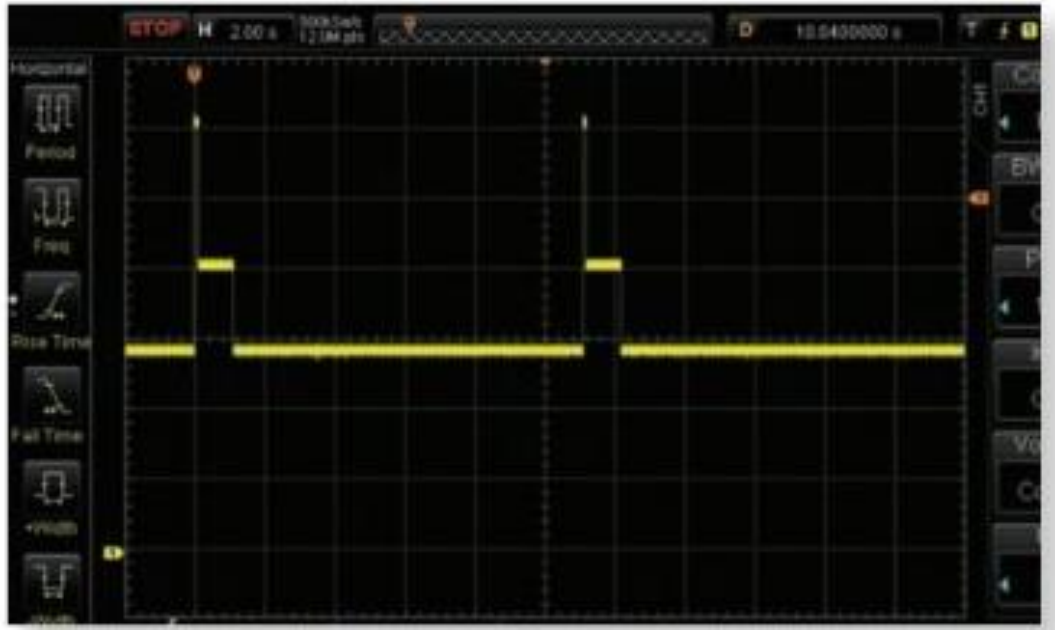
RTCA DO-160



Momentary Power Interruptions
Section 16.5.1.4b Test Condition 7

Example of DC Waveforms

RTCA DO-160



Abnormal Surges
Section 16.6.2.4_catB_28V

Normal Surge
Section 16.6.1.4c_catZ_270V

MIL-STD-704 vs RTCA/DO-160

Feature	MIL-STD-704	RTCA/DO-160
Purpose	Standardizes power characteristics for military aircraft systems	Defines environmental and EMI conditions for commercial avionics
Power Types	AC: 115/200 V, 400 Hz, 3-Phase AC: 115 V, 60 Hz (ground) DC: 28 VDC, 270 VDC	AC: 115 V, 400 Hz DC: 28 VDC, 270 VDC
Focus	Strict power quality and limits for military mission-critical systems	General environmental testing including power input, EMI, vibration, temperature, etc.
Voltage/Frequency Stability	Tighter limits, especially for transient responses, frequency deviations, and voltage dips/spikes	Broader tolerances for commercial use
Transient Conditions	Defined waveforms for dropouts, spikes, surges	Includes transient tests, but usually less severe
Operating Conditions	Designed for harsh conditions: combat zones, high-G, high EMI, nuclear hardness	Civil aviation environments (commercial airlines, business jets)
Interoperability Focus	Enforces strict consistency across all military platforms	More flexibility across a wide range of equipment types and OEMs

Testing Actuators to Compliance Standards 28VDC

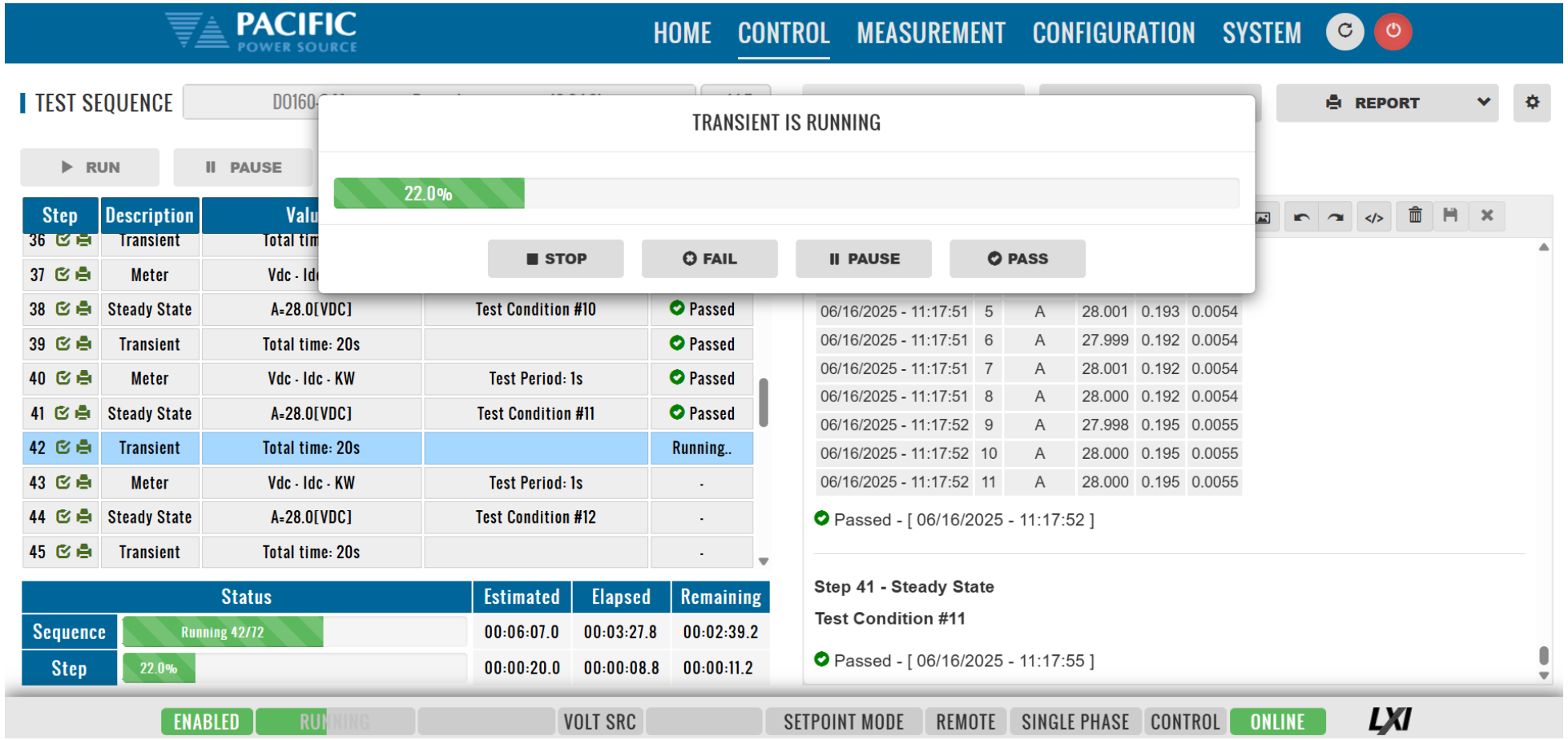
- Actuators designed to use 28VDC for operation
- DO-160 standard to test components to ensure reliable operation under harsh conditions

- RTCA-DO160
  - RTCA-DO160G
    - AC
    - DC
      - DO160-G-Abnormal-Surge-Voltage-DC.seq
      - DO160-G-Abnormal-Voltage-Steady-State-DC.seq
      - DO160-G-Engine-Starting-Under-Voltage-Operation-DC.seq
      - DO160-G-Exposed-Voltage-Decay-Time-DC.seq
      - DO160-G-Low-Voltage-Conditions-DC.seq
      - DO160-G-Momentary-Power-Interruptions-DC
      - DO160-G-Momentary-Undervoltage-Operation-DC.seq
      - DO160-G-Normal-Surge-Voltage-DC.seq
      - DO160-G-Normal-Voltage-DC.seq
      - DO160-G-Ripple-Voltage-DC.seq

28VDC actuator

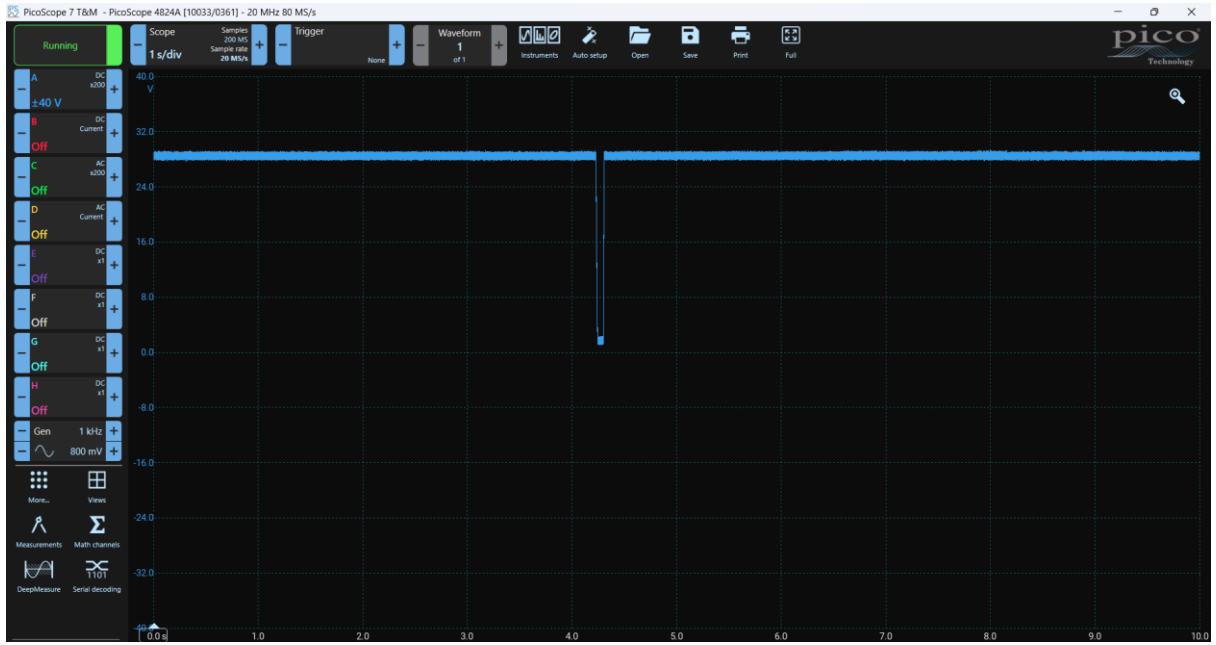
Momentary Power Interrupt Testing

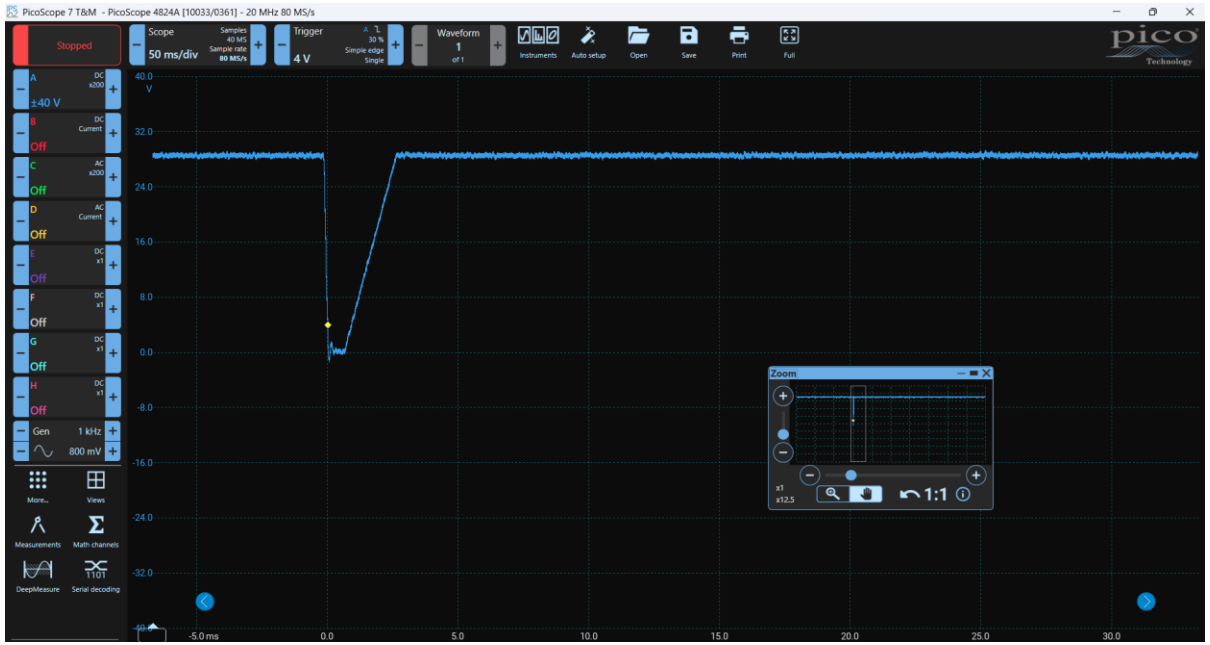
- Pre-written test sequence to automate testing



Momentary Power Interrupt Test Measurements

- Simulating real-world voltage drop out. Precise and repeatable.





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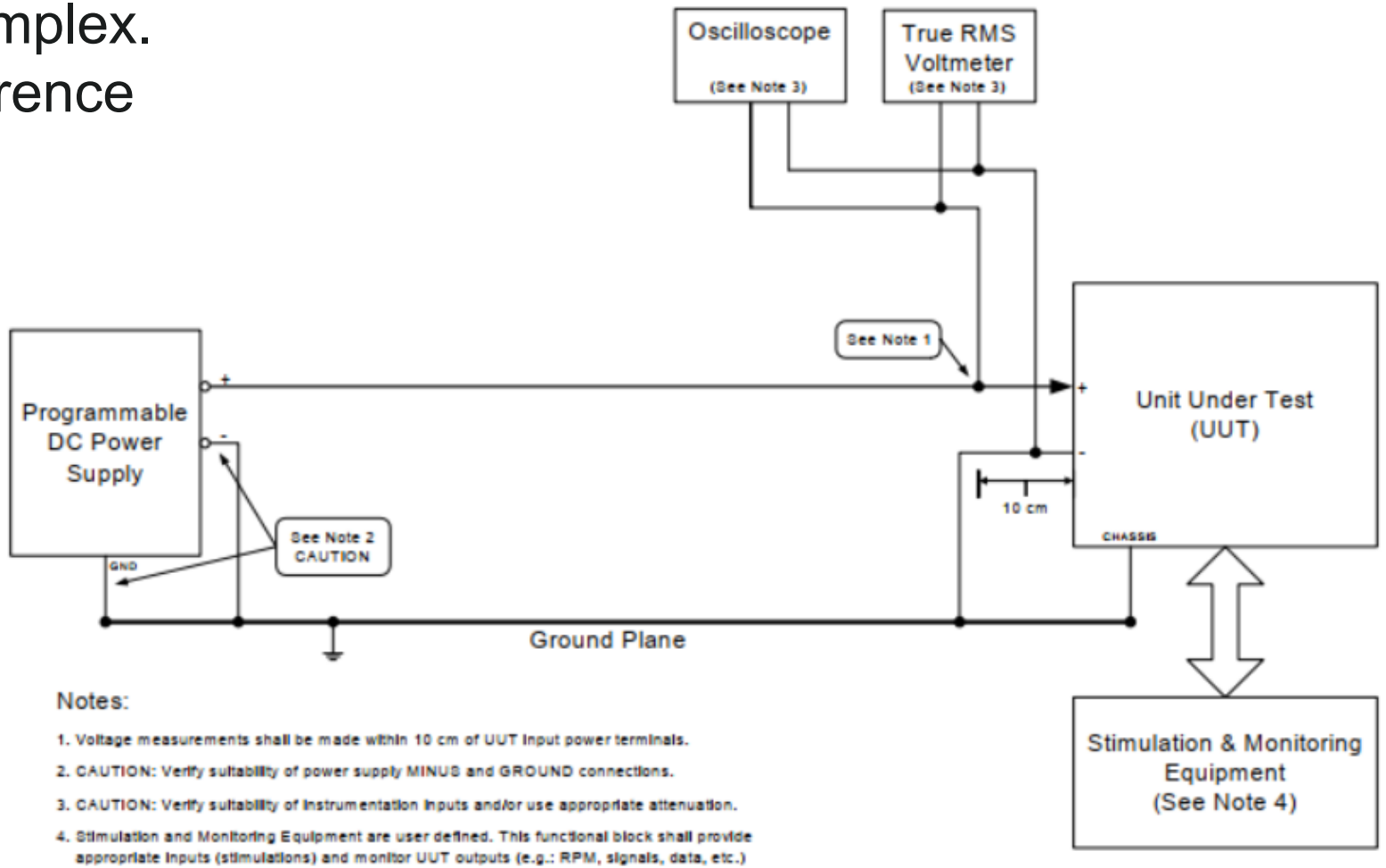
Selecting the Right Test Solution

Compliance Testing Set-Ups

Setups vary and can be complex. The standard provides reference diagrams for test setups.



Notes:

1. Voltage measurements shall be made within 10 cm of UUT input power terminals.
2. CAUTION: Verify suitability of power supply MINUS and GROUND connections.
3. CAUTION: Verify suitability of instrumentation inputs and/or use appropriate attenuation.
4. Stimulation and Monitoring Equipment are user defined. This functional block shall provide appropriate inputs (stimulations) and monitor UUT outputs (e.g.: RPM, signals, data, etc.)

FIGURE LDC501-1. Starting operation - starting voltage transients.

Criteria for Selecting Aerospace Test Solutions

Category	Key Considerations
1. Frequency Range	Support for 400Hz and 360–800Hz wild frequency; fine frequency resolution
2. Voltage Range	Common avionics levels (115/200V AC, 28V/270V DC); transient headroom
3. Waveform Fidelity	Low THD (<1%), arbitrary waveform capability • Log and analyze fast transients and faults. • High fidelity output: low THD, fast response.
4. Output Power & Current	Match UUT + test load; peak current support for surge tests
5. Transient Response	Fast voltage/frequency transitions; µs-level control
6. Flexible Configuration	Single and three-phase output; phase control for unbalance/dropout; Mixed channel configuration if needed
7. Programmable Impedance	Adjustable source impedance for degraded bus simulations
8. Linear vs Switching	Understanding the difference and when linear supplies are needed
9. Safety	Safety and protection limits, full galvanic isolation
10. Software & Automation	Multiple control options, easy to use interface, pre-built test scripts

Types of AC & DC Power Sources & Loads

Power Sources

1. Regenerative vs. Uni-directional
2. AC, DC, AC+DC
3. Linear vs Switching

Loads

Regenerative vs Non-Regenerative

Programmable AC/DC sources with:

- Arbitrary waveform generation
- Fast slew rates, low THD
- Variable frequency AC + HVDC support
- Various output configuration: 1Φ/3Φ AC & DC
- Programmable frequency & voltage ramps
- Building and creating transients
- Bidirectional capability for power absorption

Electronic Loads:

- Regenerative loads for back-feed simulation
- Constant current/power/resistance
- Creating transient
- Inductive/reactive load simulation

Linear vs Switching – The Pros & Cons

Linear

- Very low output distortion, high precision
- Low ripple
- Wide output bandwidth
- High crest factor handling without waveform distortion
- Wide range of output impedance control
- Quiet operation
- More complex transient waveforms

But less efficient, larger in size and weight

Switching

- Smaller size, lighter
- More efficient operation, lower temperature
- Moderately low output distortion
- Wide output voltage/current range
- Bidirectional / Regenerative capability
- Moderately wide output bandwidth
- Moderate range for active output impedance control

AGX: High Performance AC/DC Source

Parallel up to 756kW– up to 21kVA in 4U chassis

- **130% Overload Capability for 2s**

- **High Power Density** – 6kW up to 21kW in 4U
- **AC/DC Power Source, Current Source; Load Option**
- **Modular & Scalable Power**
  - Parallel multiple cabinets up to 252kW
  - High Power Three Phase Systems up to 756kW
- **Constant Power Voltage Range**:
  - 350Vac L-N/606Vac L-L or ±500Vdc
- **Wide Frequency Range**:
  - DC, 15Hz - 1200Hz; Extended Range 1Hz - 3000Hz
- **AC, DC and AC+DC Capability**
- **Ultimate Flexibility**
  - Single, Split, Three-Phase; Multi-Channel Mode
  - Galvanic Isolation (Inter-channel, input/output)
  - Simultaneous AC & DC Operation in a Single Phase
  - Automatic Switching of Output Modes
- **SiC Technology**
- Exceptionally **High AC Current**
- **Advanced** Waveform Digitizer
- **SmartSource Suite** Remote Control Software

AGX Highlights

High Performance, All-in-1 Capable

Regenerative, Bidirectional

High Power Density, Compact

AC/DC Ultra-Flexible 6 Form Configurations

AZX: All-in-1, Highest Performance

Parallel up to 1.1MVA+; 30, 45, 55kW models

- **All-in-1 AC/DC Power Source, Current Source, Load AND PHIL included**
- **Constant Power Voltage Range**:
  - AC Voltage Ranges: 0-240 Vac L-N / 0-415 Vac L-L and 0-480 Vac-LN / 0-830 Vac-LL
  - DC Voltage Ranges: 0-340 Vdc and 0-680 Vdc
- **Highest Frequency Range**:
  - DC, 15Hz - 1000Hz; **Or 1Hz – 10,000Hz Extended Mode**
- **AC, DC and AC+DC Capability**
- **PHIL Amplifier with High-Speed Analog I/O**
- **Ultimate Flexibility**
  - Single, Split, Three-Phase; Multi-Channel Mode
  - Galvanic Isolation (Inter-channel, input/output)
  - Simultaneous AC & DC Operation in a Single Phase
  - Automatic Switching of Output Modes
- **SiC Technology**
- Exceptionally **High AC Current**
- **Advanced** Waveform Digitizer
- **SmartSource Suite** Remote Control Software

AZX Highlights

All-in-1 Value; Highest Performance, Highest Frequency

Regenerative, Bidirectional, High Power

Widest Operating Range
(high power, dual range, extra current)

PHIL Optimized for P-HIL

AFX: Unidirectional AC & DC Source

Up to 180kW– 6kVA up to 15kVA in 4U chassis

- **85% Energy Efficient**
- **Single, Split, Three-Phase**
- **High Power Density** – 15kW in 4U
  - Parallel multiple cabinets up to 180kW
- **Modular & Scalable Power**
- **Constant Power Voltage Range**:
  - 333V L-N/576V L-L/425Vdc
- **Wide Frequency Range**:
  - 15Hz-1000Hz
  - Extended Range 1-3000Hz
- **AC, DC, AC+DC**
- **Ultimate Flexibility**
  - Galvanic Isolation (Inter-channel, input/output)
  - Automatic Switching of Output Modes
- **SiC Technology**
- **SmartSource Suite** Remote Control Software
- **Unique Sleep Mode** saves energy and extends product lifecycle

AFX Highlights

85% Energy Efficiency

Wide Operating Range, High Frequency

Ultra Flexible Configuration

Advanced Transients

LMX: Linear AC Power Source

Cleanest Power, Lowest Distortion, 500VA to 30kVA

312LMX– 1200VA in 3U

320LMX – 2000VA

18kVA Three Phase LMX

LMX Highlights

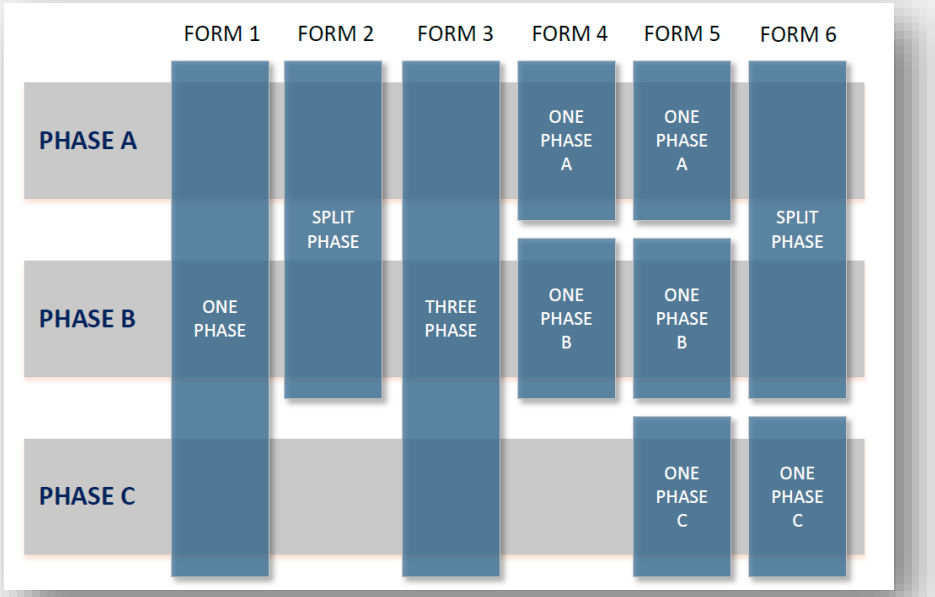
- Very Low Output Distortion & Impedance
- Reliable & Stable Power
- Highest Bandwidth, Crest Factor, Start-Up Surge Current
- Very High Frequency up to 5000Hz

- **Voltage Range**: Voltage Range: 500 VA to 6000 VA Direct: 0-135 VAC L-N / 0-234 VAC L-L 3ø (T-Option:0-338 VAC L-N / 0-585 VAC L-L 3ø 15 - 5000 Hz)
- **Frequency Range**: 15 - 5000Hz
- **Single, Split, Three Phase**
- **Less than 0.1% Vthd Distortion up to 450Hz**
- **Ripple and Noise less than -72dB**
- **Precise Output Voltage and Load Regulation**
- **Phase Angle Programming** on 3ø Models
- **Advanced Measurement, Scope Function & Waveform Digitizer**
  - Metering of Volts, RMS Current, Peak Current, Apparent Power & True Power
  - Harmonic Measurements
  - Sine, Square, Triangle, Clipped Sine, Arbitrary Waveforms Selections
  - Output LIST, PULSE and STEP Mode
  - Transient Programming
- **Programmable Impedance**

Ultimate Flexibility with 6 Phase Configurations

- ✓ **Extensive control** over voltage, current, frequency, phase angles and transients
- ✓ **Flexibly test** a wide range of grid-tied conditions and EUTs
- ✓ Configure in **source OR load** mode
- ✓ Capability to **operate in each phase as a different function**: voltage source, current source, or load (option)

Simultaneous AC & DC Operation on a Single Channel



Automatic Switching of Output Modes

Multiple Output Modes

- FORM1 – Single Phase
- FORM2 – Split Phase
- FORM3 – Three Phase
- FORM4 – Two Independent Outputs
- FORM5 – Three Independent Outputs
- FORM6 – Split Phase + Single Phase Outputs

SmartSource Suite

Proprietary Web Browser Interface with Full On-Premise or Remote Control

Run Tests in Real-Time

- Create, save & store test parameters
- View individual steps & measurements
- View test results on multiple windows

Full Control Anytime, Anywhere

- Embedded software, no drivers required
- No resource burden on the user
- Secure access from any device via user's wireless or ethernet cable access

Increase Productivity

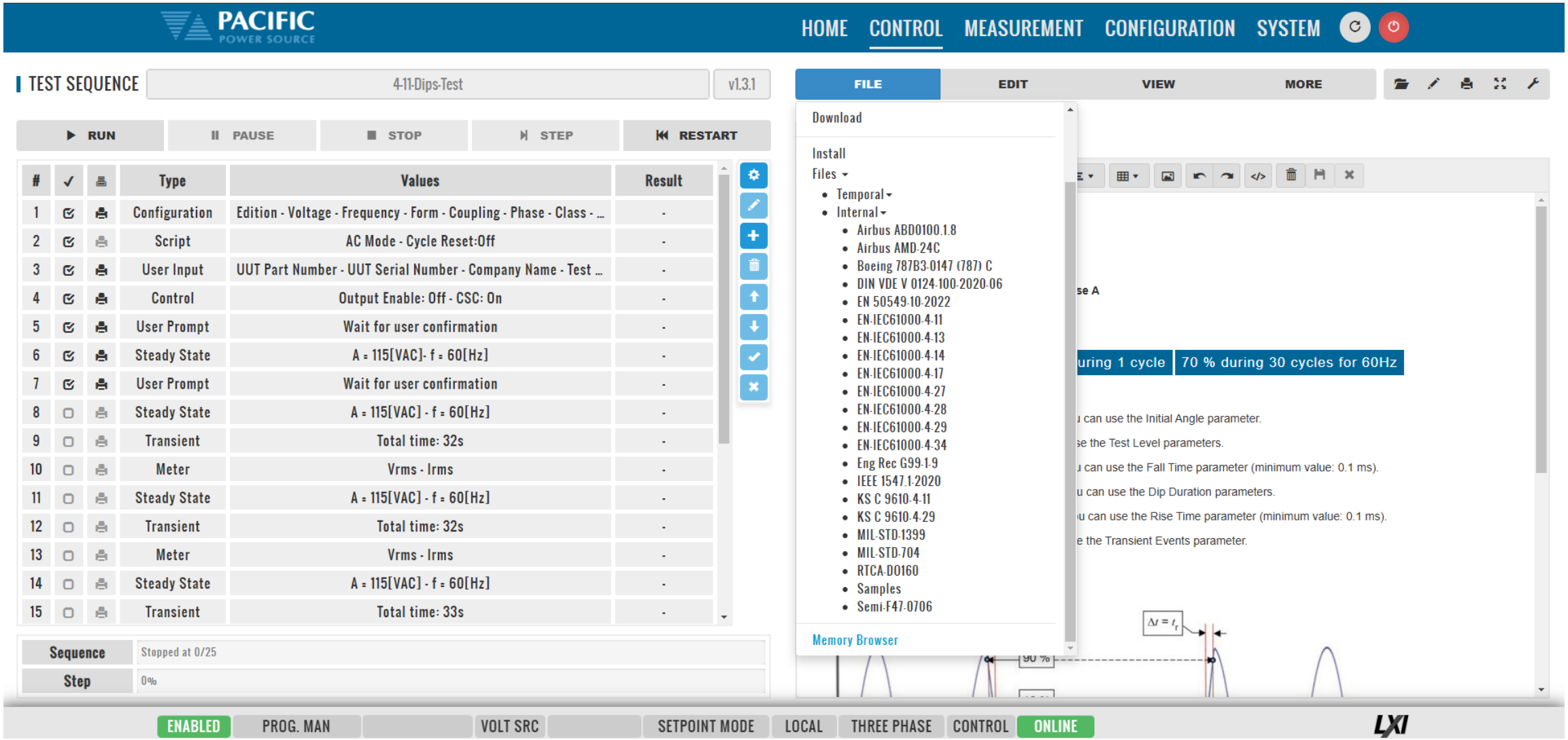
- Say good-bye to Windows and VISA Drivers
- Save time with intuitive user interface
- Optimize testing with built-in program tools
- Easily create sophisticated test sequences

Pre-Written Avionics Test Sequences

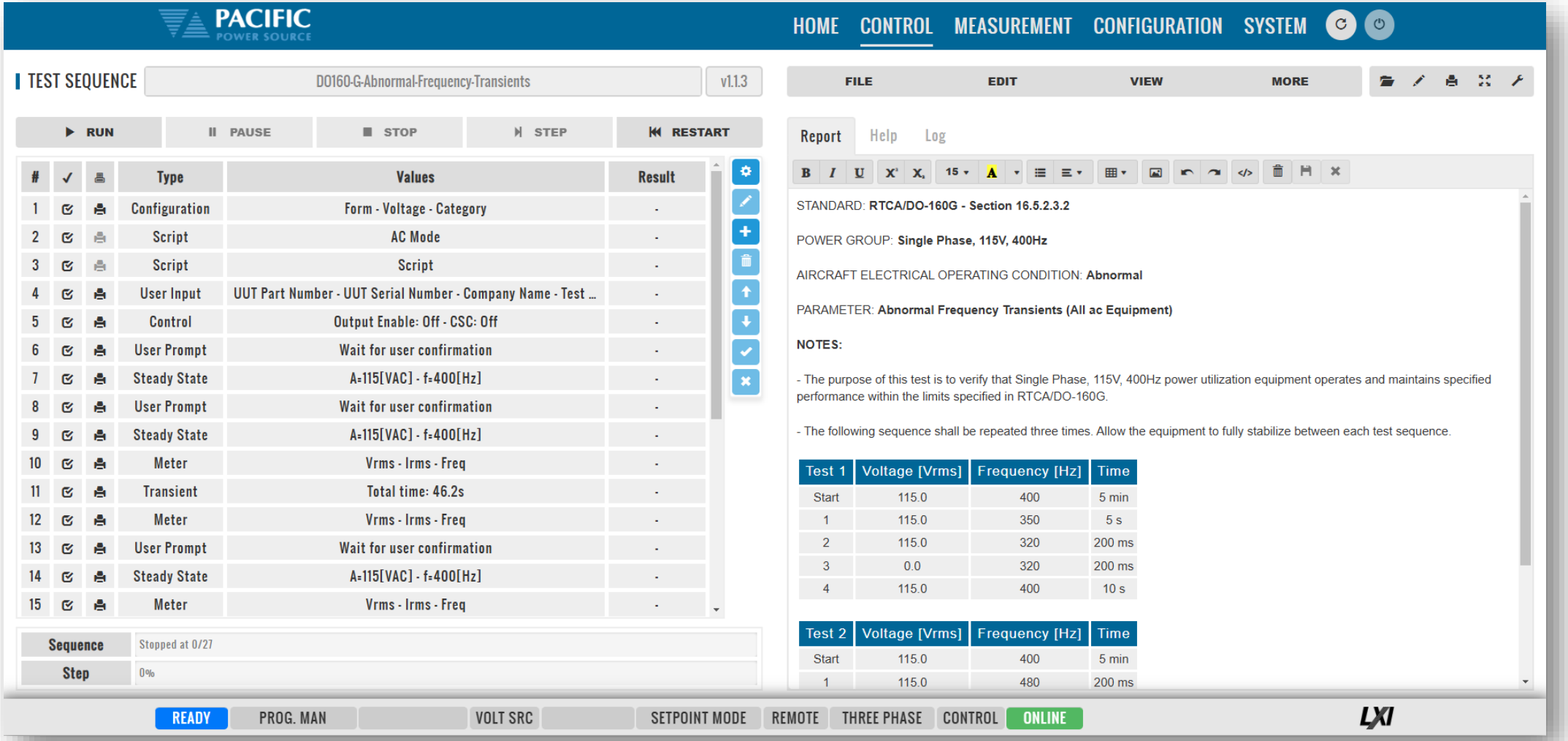
Easily test to avionics standards with our test sequence option.

- ABD0100.1.8 - Airbus A380, AC & DC Power Groups
- ABD0100.1.8.1 - Airbus A350, AC & DC Power Groups
- AMD24C - Airbus A400M, AC & DC Power Groups
- Boeing 787B3-0147 - B787, AC & DC Power Groups
- MIL-STD704 - US DoD, AC & DC Power Groups
- RTCA-DO160 Section 16, AC & DC Power Groups

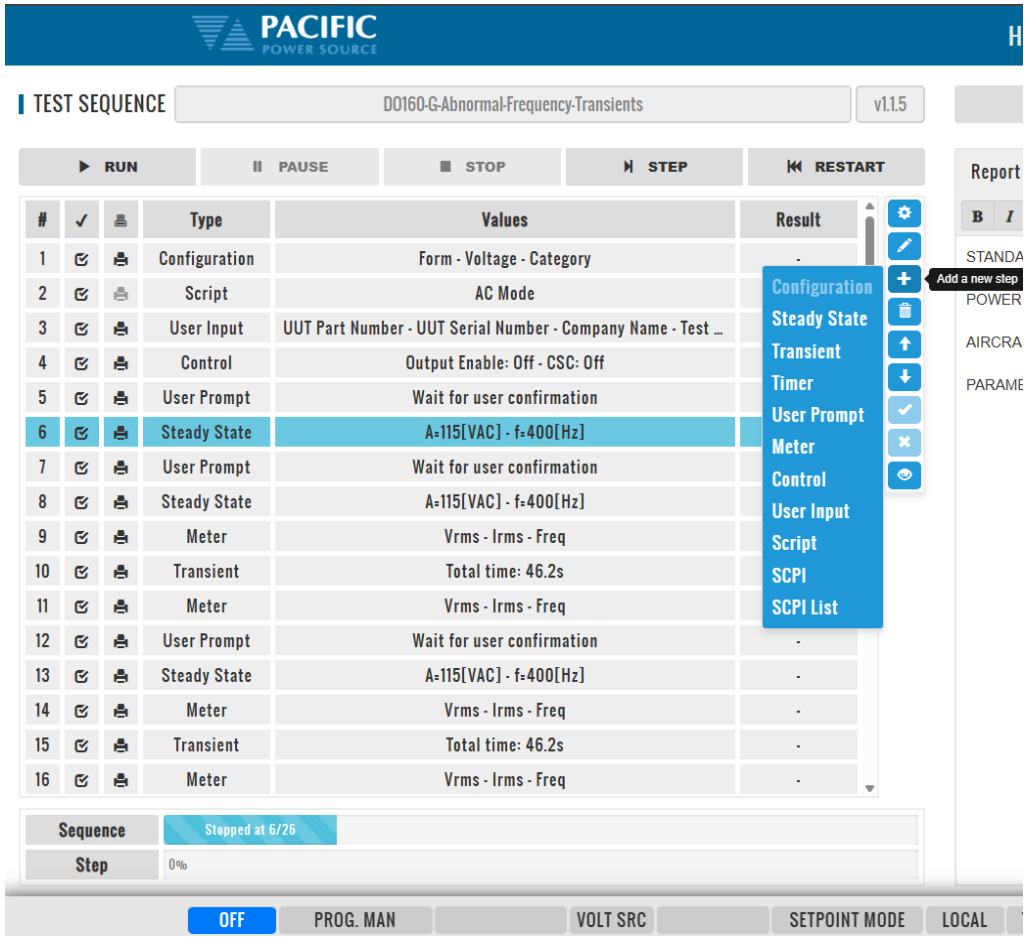
Pre-Written Test sequences / Standards List

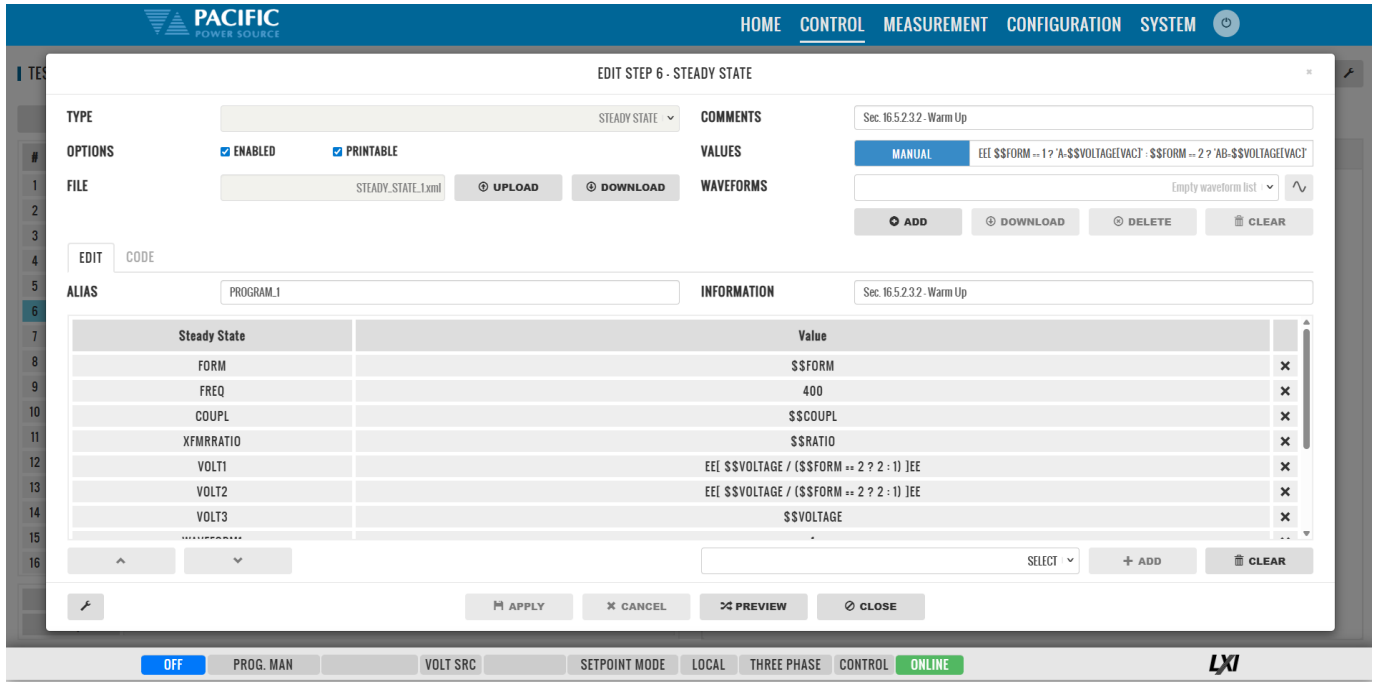


Example of DO160 Abnormal-Frequency-Transient tests



Edit and Modify Test Sequences



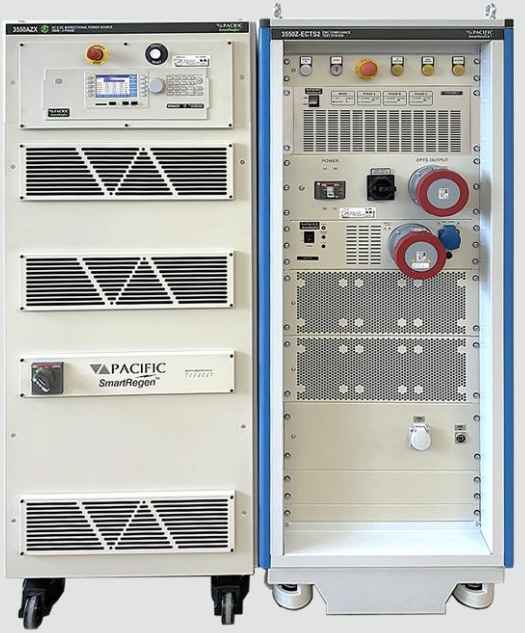


Comprehensive Test Solutions

AC Power Sources & Loads

Bidirectional DC Power Source

EMC Testing: Emissions & Immunity



Thank you! Questions?

Quick Links

- AGX Grid Simulator 6kVA to 756kVA
- AZX High Power Source up to 1.1MVA
- AFX Unidirectional AC & DC Power Source
- LMX Linear Power Source
- SmartSource Suite Control Platform
- Avionics Test Standards Brochure
- Request a Quote

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