# High Power Alternator Test Unit (ATU) Electrical System Test

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**Abstract.** The Alternator Test Unit (ATU) in the Lunar Power System Facility (LPSF) located at the NASA Glenn Research Center (GRC) in Cleveland, OH was used to simulate the operating conditions and evaluate the performance of the ATU and it's interaction with various LPSF components in accordance with the JIMO AC Power System Requirements. The testing was carried out at the breadboard development level. Results of these tests will be used for the development and validation of analytical models for performance and lifetime prediction.

# Operational Results from a High Power Alternator Test Bed

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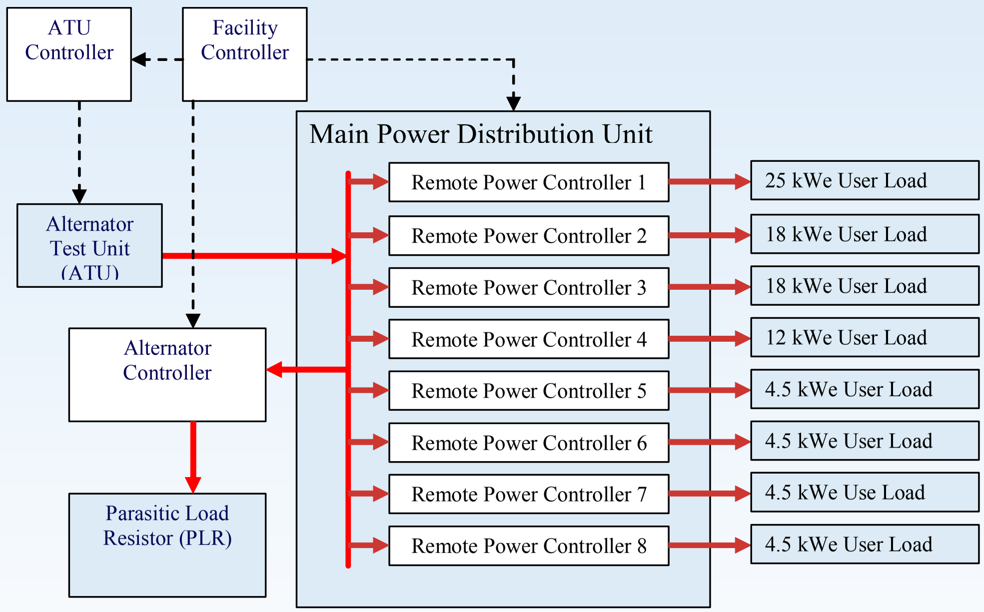
# OUTLINE

- INTRODUCTION
- LUNAR POWER SYSTEM FACILITY (LPSF) DESCRIPTION
- TEST RESULTS
- CONCLUSIONS

# INTRODUCTION

- Dynamic power systems are being proposed for Lunar and Mars surface power systems.
- One possible high power dynamic conversion system option utilizes a Brayton Power Conversion Unit (BPCU) using a permanent magnet alternator.
- A higher power electrical testbed was desired in order to evaluate the electrical control issues and system performance characteristics at representative conditions for Fission Surface Power Systems (FSPS) with multiple independently switched user loads.
- To meet these needs, the Lunar Power System Facility (LPSF) was developed and built
- The two primary objectives of the LPSF
  1. obtain test data to influence the power conversion design
  2. assist in developing primary power quality specifications prior to any system design activity.

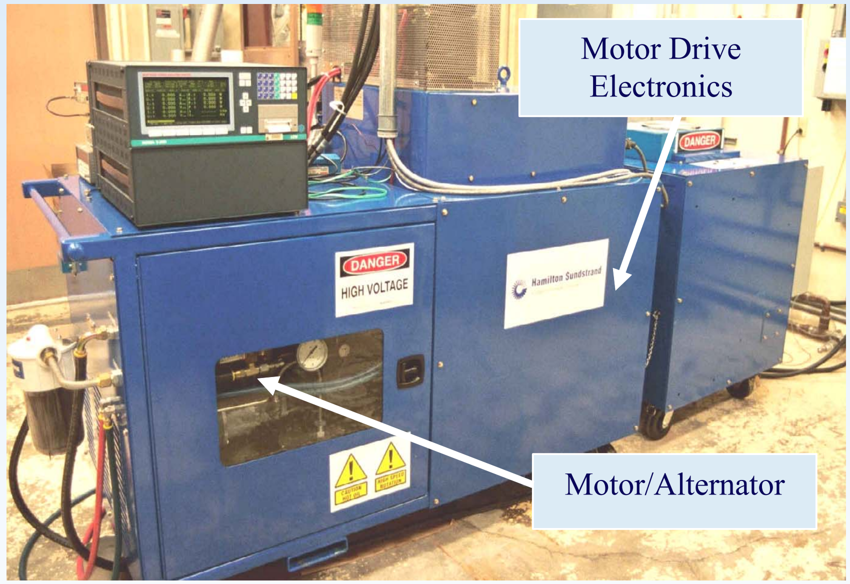
# Lunar Power System Facility (LPSF) Description




- The LPSF contains an Alternator Test Unit (ATU), a Main Power Distribution Unit (MPDU), user loads, and an alternator controller using a Parasitic Load Resistor (PLR).

# LPSF Description

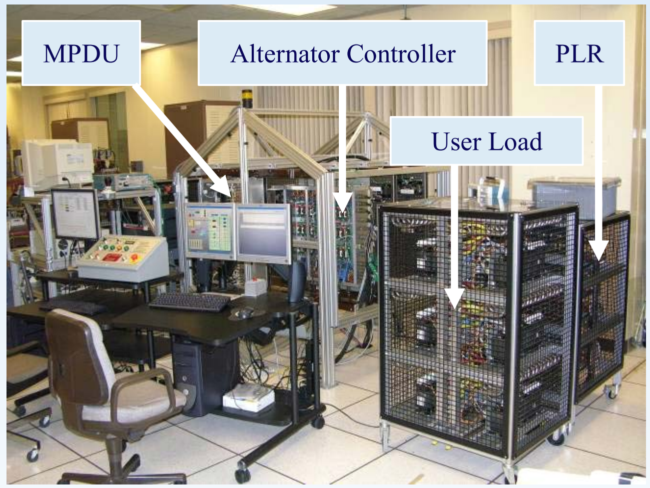
## ATU




- The ATU is the power supply for the LPSF.
- A variable speed 2-pole samarium cobalt permanent magnet brushless motor drives the alternator in place of a Brayton cycle power system.

# LPSF Description

## MPDU




- MPDU contains mechanical relays or contactors that distribute power from the ATU to the user loads and to the parasitic load resistor.
- MPDU is sized to handle 50 kW at 400VAC line to line rms, 3 phase, 1750Hz (35,000 rpm ATU shaft speed).

# LPSF Description

## Alternator Controller and PLR

- Since the alternator or ATU is nominally operated in the torque mode to simulate the Brayton turbine drive, the function of the alternator controller and PLR is to maintain a constant bus voltage and ATU shaft speed regardless of user loading.
- The alternator control function is based on applying a parasitic load to the alternator output to maintain total load as required for the desired output voltage and/or speed.
- The alternator controller consists of two main circuits
  1. the power circuits including the parasitic load elements, and
  2. the sensing circuits and feedback control loops sending the control signals to the power circuits.

# LPSF Description

## User Loads

- The main lunar power system loads would be for support of the habitat, communications, and scientific instruments.
- For the Test Bed these loads will be powered directly from the main distribution bus with a 400VAC line-to-line 3 Phase, 1750Hz feed.
- These loads implement a 3 Phase Transformer-Rectifier that change the AC voltage level and then rectify and filter to provide DC to the load.
- AC load interface is implemented as 12 pulse transformer rectifiers.
- The advantage of 12 pulse over 6 pulse rectifiers, is significantly reduced load voltage ripple, significantly reduced AC voltage and current harmonics, and greatly improved Power Factor.

# LPSF Description

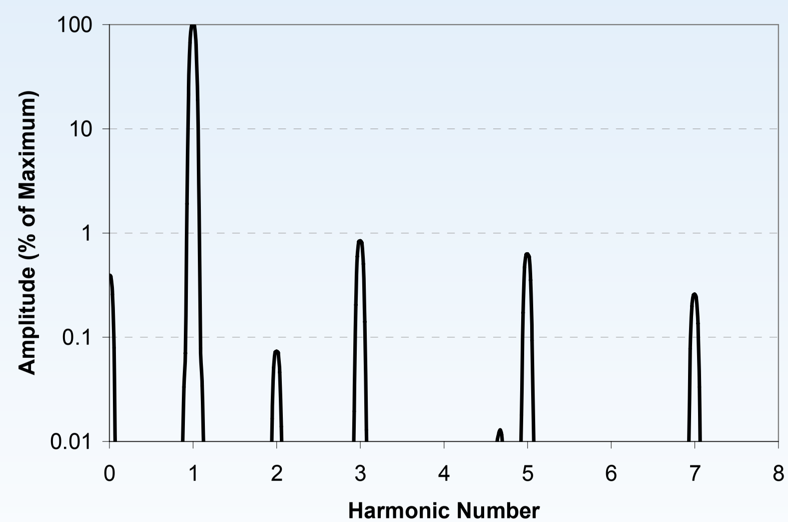
## User Loads

- It is important to represent the electrical behavior (rectification, power factor, harmonics, etc.) of these loads.  Therefore, each of these loads will be implemented with its own transformer rectifier unit supplying the required power to a resistive load bank.
- However, the output voltages for the transformer rectifier units in the LPSF may be different from the voltages that the actual loads will require.

# TEST RESULTS

## ATU Performance Using Test Resistance

- ATU first run with purely resistive load to baseline performance
- Test conditions were 35,000 rpm and 50 kW with the ATU controller in speed control mode
- Test results are shown normalized as percentages of the first fundamental frequency at 1750 Hz




- These results show that the maximum higher order harmonic is less than 1%.  This occurs at the 3rd harmonic.

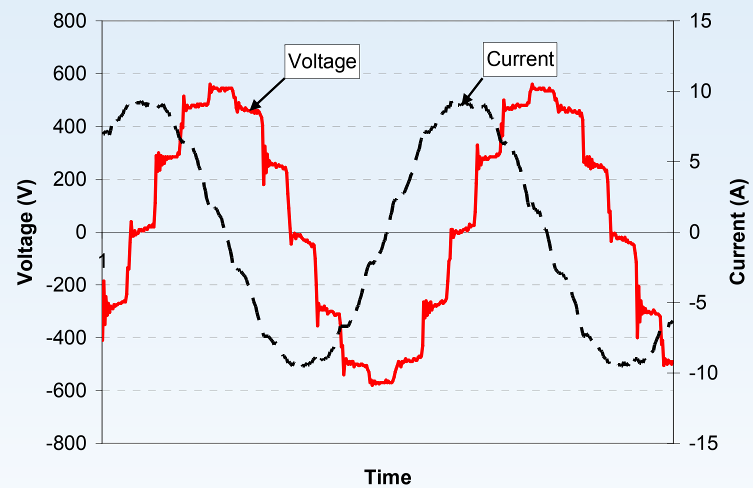
# TEST RESULTS

## ATU Voltage Harmonics Using MPDU

- ATU was then connected to the MPDU
- Tests were performed at 50 kW and 35000 rpm with the controller in speed control
- There were two test load conditions
  1. 100% user loads and
  2. 100% PLR

# TEST RESULTS

## ATU Current and Voltage Waveform

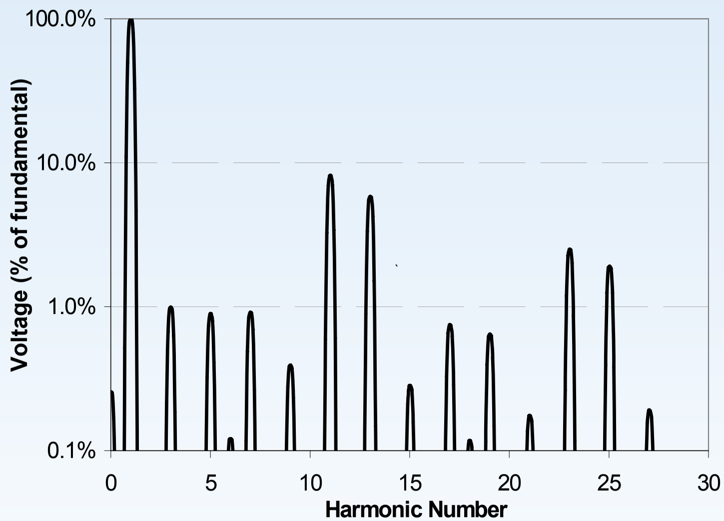


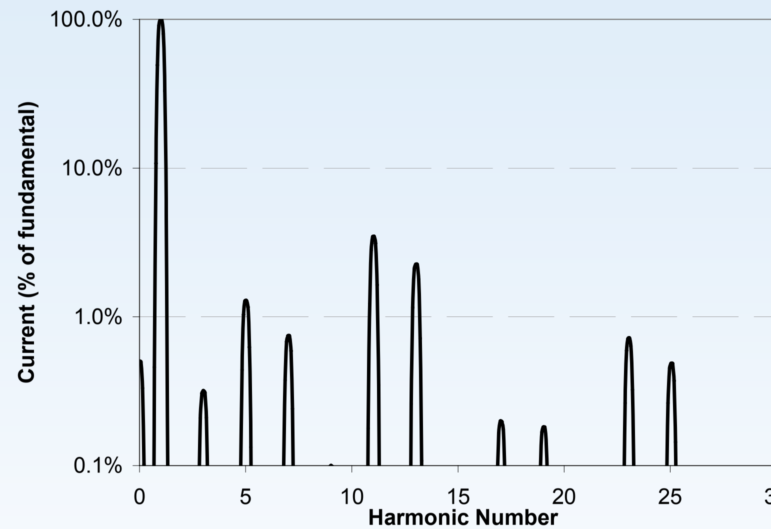

- This chart represents the 100% user load condition
- user load 12 pulse rectification is clearly evident in the stepwise appearance of the ATU voltage waveform.
- the phase difference between the waveforms occurs because:

1. Voltage is measured line-to-line,
2. Current is the line current and,
3. A measured power factor of 0.97. This compares favorably to the theoretical 12 pulse system power factor of .98.

# TEST RESULTS

## ATU Current Harmonics Using MPDU

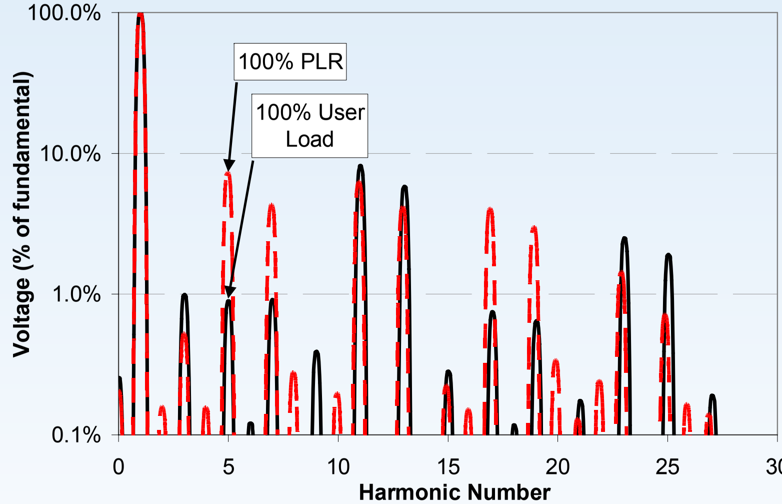


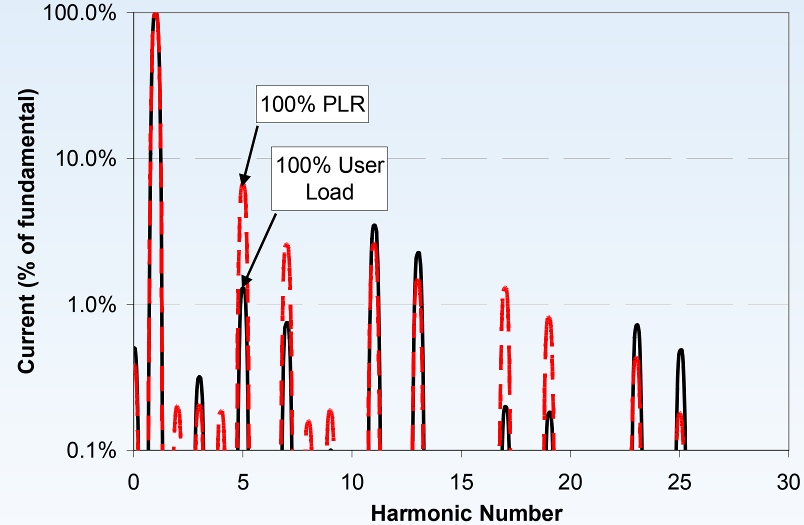




- Electrical current spectrum harmonics are lower amplitude than the voltage harmonics due to the inductance of the alternator.

# TEST RESULTS

## ATU Current Harmonics Using MPDU




- The full PLR loading case resulted in slightly worse harmonics, particularly the 5th and 7th harmonics that theoretically should not be present in a 12 pulse system.
- The cause of these harmonics is unbalance in the PLR transformers.

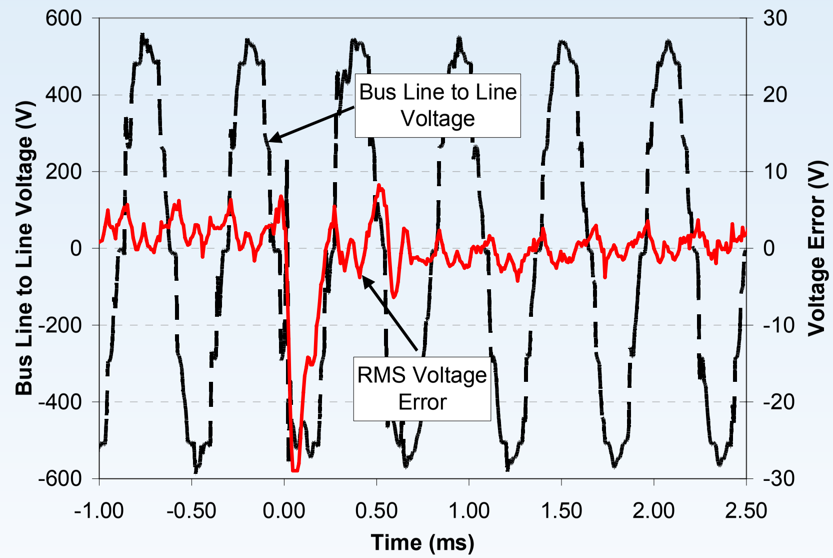
# TEST RESULTS

## ATU Power Transient Response to Load Application and Removal

- Power transient response to load application and removal was investigated.
- ATU was operated on torque control at 35,000 rpm and approximately 50 kW.  A small load (4.5 kW, load “A”) was applied and the motor torque was increased to achieve a relatively high PLR load.
- A large load (18 kW, load “B”) was then switched on and off to observe the effect on the AC bus voltage and load A’s DC voltage.

# TEST RESULTS

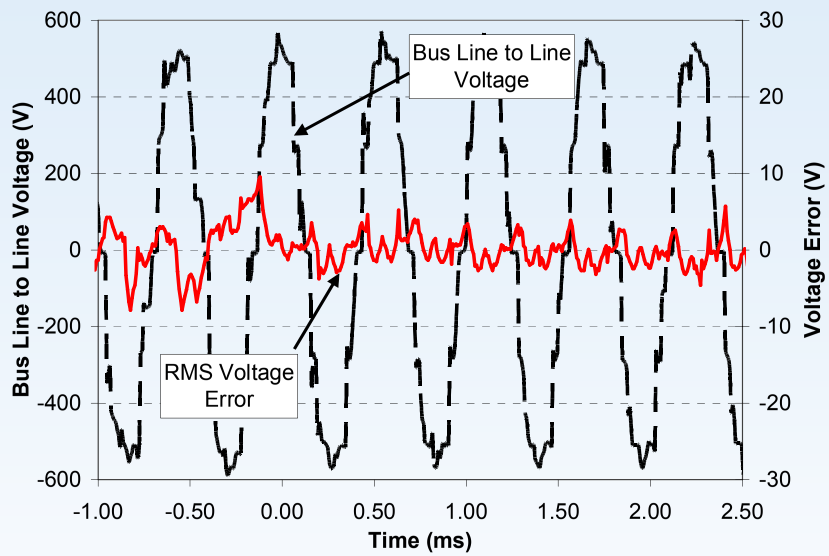
## ATU Power Response to Load On Condition




- Bus line to line voltage and RMS voltage error in response to the load-on condition.
- The voltage drop shown in the RMS voltage error is due to the comparatively large inrush current to charge the filter in the load.

# TEST RESULTS

## ATU Power Response to Load Off Condition




- Bus line to line voltage and RMS voltage error in response to the load-off condition.
- voltage overshoots, by only a couple percent, with a slightly faster recovery than the load on condition.

# CONCLUSIONS

- This testing demonstrated some of the operational abilities of a permanent magnet alternator to provide 3-phase AC power to various loads employing a Wye-Delta transformer in combination with direct 12 pulse rectification of the power bus for user loads.
- It furthermore demonstrated the ability of a high power alternator control scheme based on shunt loading of the alternator output to successfully regulate output bus voltage and alternator shaft speed.