Deep Space One
High-Voltage Bus Management

Jet Propulsion Laboratory
Donald Nieraeth
Ken Rachocki
Spectrum Astro, Inc.
California Institute of Technology

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Overview

Final HPDC Design and Build
Preliminary Design of HPDC
Industry Partner for Deep Space 1
Deep Space 1 Mission

Curt Copeland
Al Arens
Spectrum Astro
California Institute of Technology
Jet Propulsion Laboratory

Acknowledgments:

Conclusions
Flight Data & Analyses
Operations
Testing & Stability
Design & Fabrication of High Voltage Power Converter
High Voltage Bus Requirements

Don Nieraeth
Ken Rachocki
paramount in accomplishing the mission goals.

As the available power from the solar array power decreases as the square of the distance from the sun, the need to operate near the peak power point is significant.

Significance of the Requirements

Provide Current and Voltage Telemetry from Solar Array and Batteries

Load Each of 8 Solar Cell Modules to Measure I-V Profiles of Array Segments

Provide Battery Charge Control

33+1/-11V @ 18.2 A Maximum For Spacecraft Power

High Switching for PPU & PPU Heaters (2500W, 100W & 70W, Respectively)

Other HPCU Design Requirements

To support S/C loads occasionally during IPs thrusting.

The power subsystem has to allow the battery for the spacecraft to reach the asteroid.

HIGH VOLTAGE BUS REQUIREMENTS
Operation:
Keep the PPU from getting too cold during low power and "off".

PPU Heaters
- Designed to provide over 2300 W of output power.
- Converts high voltage to seven voltages to drive an Ion Thruster.

Power Processing Unit (PPU) - part of the Ion Propulsion Subsystem (IPS)
- and trickle charging.

V-T (voltage-temperature) curves to account for cell aging, cell short,
- Includes a charge control unit to charge the battery based on one of 16
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A to the engineering loads and science instruments.
- Converts high voltage to low voltage (~32 Vdc) while providing up to 16
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High Voltage Power Converter Unit (HPCU) - Original Requirements
- Estimated output power is 2500 W at 1 a.u. from Sun.
- Output voltage range is from 80 V to 120 Vdc.

Solar Array

THE HIGH VOLTAGE BUS INTERFACES
Based on the projected estimates of the PPU voltage, the array voltage regulation set-point is selected near the PPU. 

- The voltage range is 78 to 132.4 Vdc in 64 x 0.85 volt steps.
- Voltage set-points in the HPUC.
- The flight operations team or on-board sequence can command any one of 64 array point selected by an up-link command.
- Additional control loop was added in the HPUC that allows regulation to an array voltage set-point.

The focus shifted to modifying the HPUC design.

Abandoned.

Since the PPU design was frozen, the decision of a PPU approach was:

- The PPU being a 2500 W load is a better choice for implementing a PPT.
- The goal was to maximize power to the PPU not the spacecraft loads.
- Initially, the use of a Peak Power Tracker (PPT) was considered.
- Incorporating a PPT in the HPUC has very limited advantage since it is a small load (~450 W).
- Including PPU (Thrustster) demanded more power than the solar array could supply.

With the original HPUC design, the array voltage would collapse if the spacecraft loads

THE HPUC DESIGN CHALLENGE
side of the PPU (without collapsing the array voltage).

On-board flight tests indicate that the HPCU can operate at a set-point voltage on either ground is near the power source.
A single-point ground approach is used on the spacecraft for power return lines; the star grounding configuration.

As expected, the magnitude of the noise on the high voltage is dependent on the collapsing the array voltage did not affect the operation of either the HPCU or the PPU.

The test results showed that although the PPU with a thruster load generated some noise on the high voltage bus, the HPCU performed in a stable manner.

Using a solar array simulator as a power source, compatibility tests were performed with a HPCU breadboard and a PPU breadboard.
autonomously.

Software algorithm on-board sends a command to IPS to throttle back one step if the battery discharges too deep (projected to reach 65% SOC in about 30 minutes), then a

from the array minus the expected spacecraft power consumption.

The IPS is commanded to a throttle level that corresponds to the maximum projected power

The set-point selection is updated every week during spacecraft tracking.

The set-point voltage set-point selected slightly to the right of the PPF.

Operating voltage set-point selected slightly to the right of the PPF.

Based on a projected PPF voltage, an up-link command is sent to the HPCU to have the array

A predetermined minimum required loads are turned on during this phase.

operate near the PPF of the array.

To provide maximum power to the IPS during the thrusting phase, the spacecraft has to

Spacecraft On-Orbit Operations
1. Upon sun acquisition, HPcu operates in battery current limit mode.

2. During nominal cruise, HPcu operates in V-I battery charge limit mode.

3. While thrusting, HPcu operates in solar array voltage control mode; the voltage set-point is near the PBP.
Results from a PPP search test performed in flight.
SUMMARY

The design of the High Voltage Power Converter Unit on DSI allows both the spacecraft avionics and ion propulsion to operate in a stable manner near the PEP of the solar array.

This approach relies on a fairly well-defined solar array model to determine the projected PEP.

The solar array voltage set-points have to be updated every week to maintain operation near PEP.

The next step for the technology is to investigate the use of onboard autonomy to change the operating power level of the ion engine.

Stable operation even to the LEFT of the Peak Power Point is achievable so long as you do not

Future missions that have one or more ion propulsion subsystems.

determine the optimum 5A voltage regulation set-point (i.e., near the PEP). This is for

DEEP SPACE.

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