MAXIMIZING OVERALL ELECTRICAL POWER SYSTEM EFFICIENCY IN PICO/NANO-SATELLITES WITH INNOVATIVE PLUG-AND-PLAY BATTERY CHARGING SYSTEM

Mr. Matthew Rodencal
Contents

• Power Point Tracking
• The CubeSat Environment
• Constant Current-Constant Voltage (CC-CV) Charging on Orbit
• The Power Management System
• Adaptive Current Charging
What are Power Point Trackers?

- Power Point Trackers moderate power drawn from the solar panels so they are at their Maximum Power Point (MPP).
- Maximum Power Point:
  - The point on the IV curve where the most power can be drawn from the solar panel.

Fig 1: IV Curve of Solar Cell

- **Thermal Environment**
  - On orbit, the temperature can fluctuate from -40 to 40°C

- **Variable Solar Power**
  
  ![Power Over 1 Orbit @ 500km, 51°, 1Hz tumble](chart)

  *Fig 2: Available Power Over 1 Orbit (data collected using STK)*
1. All power needed for constant current charging is available

Fig 3: Capacity as a function of charge voltage on a lithium-ion battery

Constant Current-Constant Voltage Charging on Orbit

Fig 4: Available Power Over 1 Orbit @ 500km, 51°, 1Hz tumble

Fig 5: Available Power Over 2 Minutes

- 200mA Charge
- 400mA Charge
- Available Power

% of Available Power Used
- 200mA = 39.7%
- 400mA = 72.7%
The Power Management System

The Power Management System is made up of 2 fundamental blocks:

- Load Matching System
- Power Path Controller

Fig 6: Simplest Form of the Power Management System
• The Load Matching System
  – Reads the input voltage and current
  – Adjusts the amount of current that the power path controller can sink using \( \frac{dP}{dt} \) controller

• One load matching system can support multiple power path controllers

Fig 7: Load Matching System
The Power Path Controller

- Supplies needed current to the output bus, charging the battery with unused current
- Provides power from the batteries when needed to maintain the output bus voltage
• Modified CC-CV charging profile
  – In “CC mode”, the Charger is allowed to charge the batteries up to a maximum safety current
  – The CV mode behaves identically to the normal CC-CV profile, unless power is needed at the output bus.

Fig 7: Available Power Over 2 Minutes
System Limitations

• Breaking the feedback loop
  – Available Current > Maximum Safety Current
    • The power management system will not charge the batteries at a higher current than is safe.
    • Available power will go unused
    • For ChargerSat-1, this is a forbidden condition
  – In CV mode or if the battery is charged, the system is unable to sink current into the battery
    • The Power Management System will not attempt to charge a full battery
    • Available power will go unused
Conclusion

- +20% efficiency boost over CC-CV profiles
- Stand-alone System
- Automatically Optimizes Power Throughput

- Suitable, without modification, for use in any situation where input power <20W
  - Reduces the need for high fidelity models
Acknowledgements

• Office of VP of Research at University of Alabama in Huntsville
• Lockheed Martin
• Lufthansa
• Space Hardware Club at University of Alabama in Huntsville
• Alabama Space Grant

Any questions, comments, concerns?
Contact me at: mgr0003@uah.edu