Overview of International Space Station Electrical Power System

Presented to
EnergyTech 2016

Francis Davies – Johnson Space Center

November 2016
The International Space Station (ISS) is a unique scientific platform that enables researchers from all over the world to put their talents to work on innovative experiments that could not be done anywhere else.

Orbit:
- Inclination: 51 degrees
- Period: 90 minutes
- Altitude: ~240 miles
• Divided into 8 separate power channels (busses)
• Arrays: Intermittent power (90 minute orbit, 30 minute eclipse)
• Batteries: Supply power during eclipse periods
• Power Distribution: handles faults
ISS Solar Arrays: Overview

Solar Array Wing (SAW):
- There are 32,800 solar cells total on the ISS Solar Array Wing, assembled into 164 solar panels.
- **Largest ever** space array to convert solar energy into electrical power
- 8 Solar Array Wings on space station (2 per PV module)
- Nominal electrical power output ~ 31 kW per Solar Array Wing at beginning of life, 8 SAW total for ~**248 kW total power**
- 4 PV modules (PVMs) on ISS, 2 power channels per module for **8 power channels total**
Operational factors for solar arrays:

- Feather for EVAs (space walks)
  - Shadows cold, sunshine hot.
- Visiting vehicles: Maneuvering rockets can hit arrays with plumes
  - Force on arrays
  - Array degradation
- Reboost
  - Forces on arrays
- Structural thermal
  - Longeron shadowing
ISS Batteries

- Consists of 38 lightweight Nickel Hydrogen cells and associated electrical and mechanical equipment, packaged in an ORU enclosure.

- During insolation, solar electric energy, regulated by the charger (BCDU), will replenish energy stores in preparation for the next eclipse cycle.

- Two ORU makes a battery. There are 24 batteries on ISS at AC.

- Present batteries are reaching the end of their lifecycles, and replacement Lithium Ion batteries are being developed.
Power distribution system operational factors:

- Load shedding:
  - Several load shed tables
  - Often needed to cope with array feathering
- Equipment failures
- EVA (spacewalk) safety
- Reconfiguration:
  - Large structural reconfigurations
  - Changes to experimental racks.
- Power balancing
  - Loads can be shifted from one bus to another to a limited degree
- Helping with troubleshooting of other systems (spikes on current waveforms)
Autonomous power functions on the ISS:

- Fault isolation (circuit breaker action)
  - Single equipment failure will not take down bus
- Battery charge and discharge
  - Optimized to reduce battery cycle life degradation
- Array orientation
  - Pointing algorithm tracks sun over orbit
ISS Electrical System Challenges

- Aging equipment
  - Extension of certification
  - Battery wear-out
  - Solar array wear-out

- Increasing amount of loads
  - Power generation capability is decreasing

- Limited crew time for on-orbit operations and maintenance
  - Extensive planning needed for activities

- Limited data rate for telemetry:
  - Most currents are 1 Hz sample rate
  - Fastest current sample rate is 50 Hz

- Test lab on the ground, but not full scale mockup
ISS assembly sequence connected large complex modules that had not been connected on the ground.

- No complete ground mockup/Iron-bird
- Extensive ground performance testing and modelling required
  - EMI: conducted emissions and susceptibility (bus ripple)
  - Load and Source Impedance for stability
  - Bus transients
<table>
<thead>
<tr>
<th></th>
<th>ISS Power System</th>
<th>Hypothetical Microgrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage type</td>
<td>DC</td>
<td>AC</td>
</tr>
<tr>
<td>Configuration changes while operating</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Intermittent power sources</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Centralized Control</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Battery Storage</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>