Overview of International Space Station Electrical Power System

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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
ISS Overview

International SPACE STATION
ISS Electrical Power System Block Diagram

- 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
ISS Solar Array Wing
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
### ISS: comparison to terrestrial microgrid

<table>
<thead>
<tr>
<th></th>
<th>ISS Power System</th>
<th>Hypothetical Microgrid</th>
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<tbody>
<tr>
<td>Voltage type</td>
<td>DC</td>
<td>AC</td>
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<tr>
<td>Configuration changes while operating</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>Intermittent power sources</td>
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<td>YES</td>
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<tr>
<td>Centralized Control</td>
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<td>NO</td>
</tr>
<tr>
<td>Battery Storage</td>
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<td>YES</td>
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